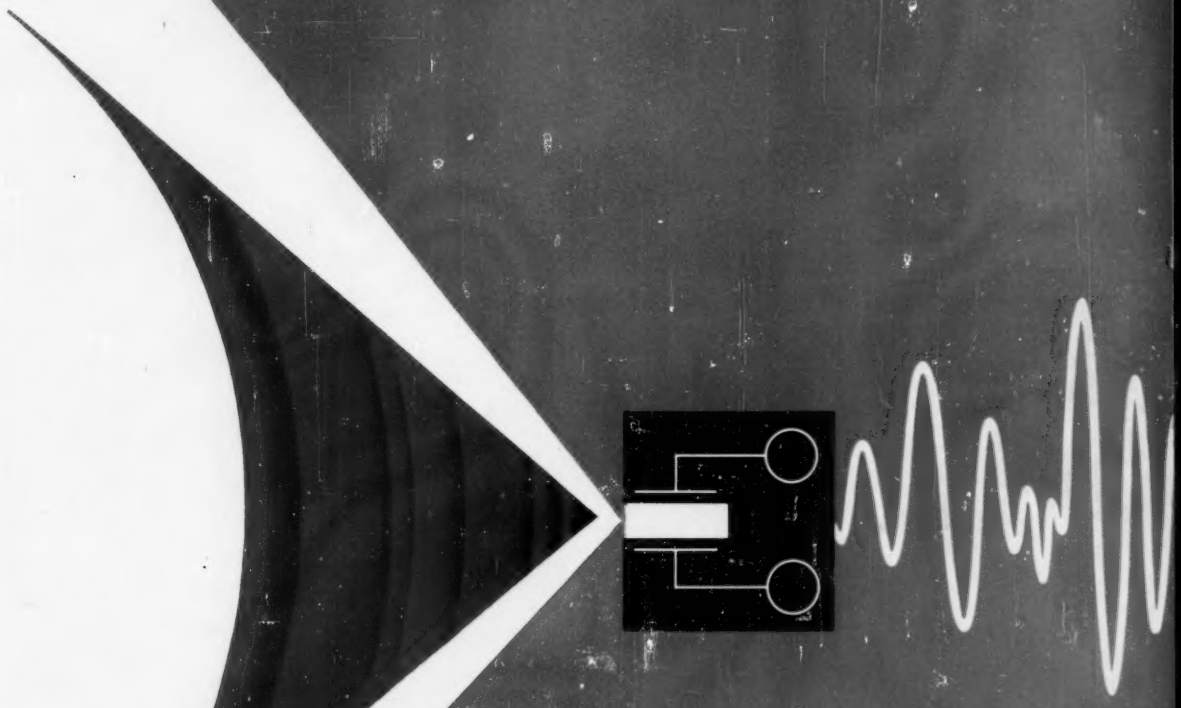
JANUARY 9, 1958

MACHINE DESIGN

A PENTON PUBLICATION — BIWEEKLY



Electromechanical Transducers

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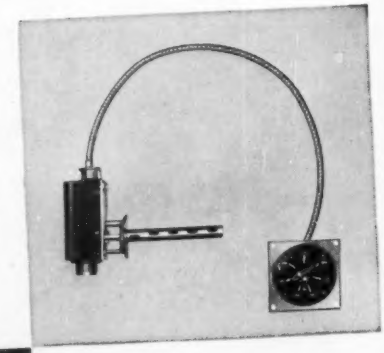
S. S. White Flexible Shafts Withstand Temperature Extremes!

A leading aircraft manufacturer has used S.S. WHITE flexible shafts for many years to transmit control between this graduated dial and aircraft thermostat. He finds that under any kind of temperature conditions, there is no measurable variation in torque to turn the shaft, or in torsional deflection required to initiate cam movement over the temperature range!

This ability to withstand temperature extremes is only one of the many remote control and power drive advantages industry has discovered in S.S. WHITE flexible shafts. Perhaps they can help you to simplify control or product design . . . cut your production costs . . . speed assembly. These quality shafts range from small to large sizes, and up to 12 feet in length. The assistance of our engineering staff in helping you work out a flexible shaft application for your product is yours for the asking. Just write to



S. S. White

FIRST NAME IN FLEXIBLE SHAFTS

USEFUL DATA on how to select and apply flexible shafts. Write for Bulletin 5601.

S. S. White Industrial Division, Dept. 4, 10 East 40th St., New York 16, N. Y. Western Office: 1839 West Pico Blvd., Los Angeles 6, Calif.

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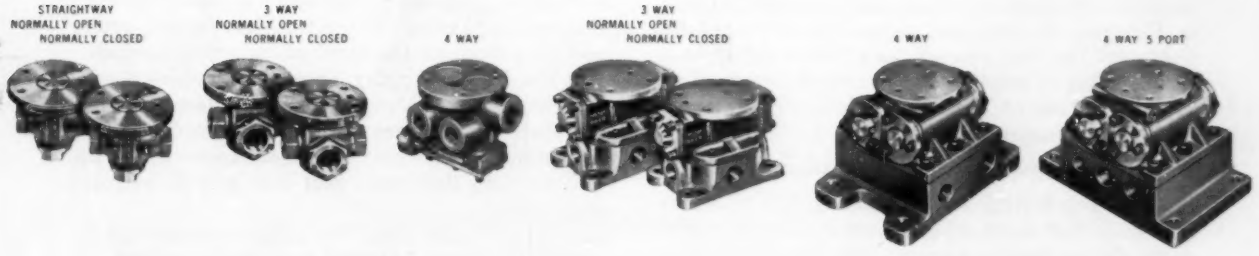
Ross Skyline

Now-All the basic valves-*and more*- in this *long life* air valve series

match any head to any valve body!


STRAIGHTWAY NORMALLY OPEN NORMALLY CLOSED
3 WAY NORMALLY OPEN NORMALLY CLOSED
4 WAY
3 WAY NORMALLY OPEN NORMALLY CLOSED
4 WAY
4 WAY 5 PORT

Now there are 11 heads and nine bodies to meet both usual and unique problems in the line which was designed to give you the longest life and greatest adaptability of any valve line in the world. All heads are readily interchangeable with all Skyline valve bodies, and the new Double-Stroke momentary adapter further multiplies the number of valve combinations. What is your problem? Drop us a note explaining it, or call your nearby Ross field service engineer for details on the Skyline valve to solve it.

Circle 404 on Page 19

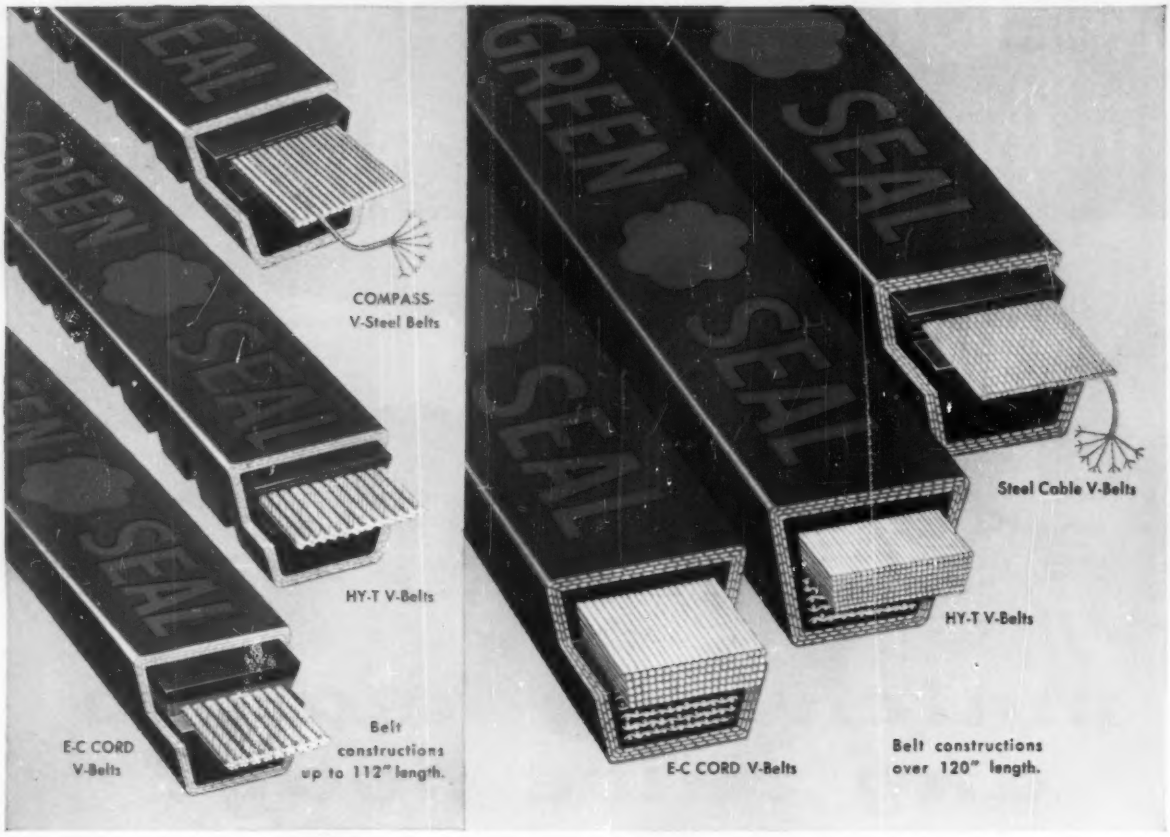
Combining Engineering With Ingenuity for Better Air Control

Ross OPERATING VALVE COMPANY

109 EAST GOLDEN GATE AVENUE • DETROIT 3, MICHIGAN

Do you know the inside story of

V-Belts with the Green Seal?



Until recently dimensional stability was possible only in V-Belts with steel load-carriers as developed by Goodyear. But now you can have that stability in a complete line of belts – thanks to the development of Triple-Tempered (3-T) cord–synthetic cord tempered by Tension, Temperature and Time.

What's your pay-off from this dimensional stability?

When you're belting multiple drives, it's your one guarantee that every set of matched belts will *really* match. No matter how long you store them, they'll *stay* matched, too.

And once they're installed, you've got belts designed and built to work as a perfect team–without individual belts either "loafing" or overworking. In fact, you're protected from all the usual mismatching headaches that also include slipping, stretching, scorching.

In other words, you're belted for maximum trouble-free horsepower hours at minimum cost. There's no substitute for that kind of performance – or for the V-Belts with the Green Seal that give it to you – every time.

So see your dealer about the V-Belts with true dimensional stability–the V-Belts with the Green Seal. Or write Goodyear, Industrial Products Division, Lincoln 2, Nebraska, or Akron 16, Ohio.

DIMENSIONALLY STABLE V-BELTS
with the GREEN SEAL by

GOODYEAR

THE GREATEST NAME IN RUBBER

Compass, E-C Cord, Hy-T, Green Seal–T.M.'s The Goodyear Tire & Rubber Company, Akron, Ohio

Watch "Goodyear Theater" on TV – every other Monday 9:30 P.M., E.S.T.

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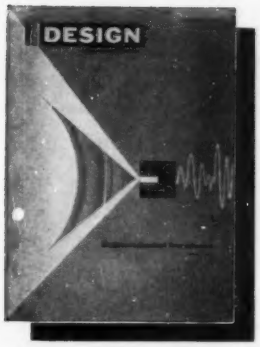

Front Cover: Electromechanical transducers, featured by artist George Farnsworth, transform mechanical energy into an electrical output for control purposes. Article by A. I. Dranetz is on Page 120.

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MACHINE DESIGN

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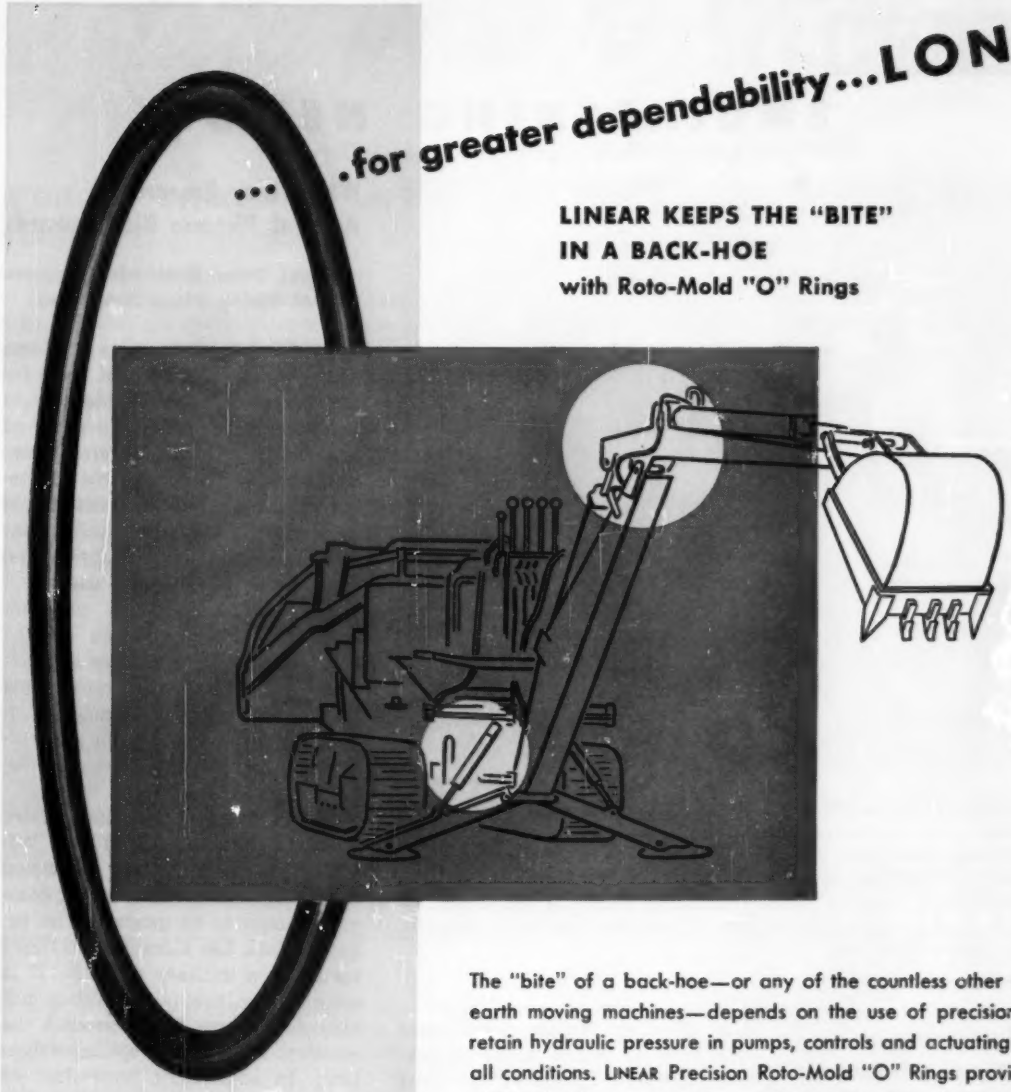
LINEAR KEEPS THE "BITE"
IN A BACK-HOE
with Roto-Mold "O" Rings



The "bite" of a back-hoe—or any of the countless other small and large earth moving machines—depends on the use of precision seals that can retain hydraulic pressure in pumps, controls and actuating cylinders under all conditions. LINEAR Precision Roto-Mold "O" Rings provide the dependability that keeps expensive equipment operating longer at peak efficiencies—around the clock.

LINEAR'S extensive experience in working with all types of elastomers enables the selection of materials that can stand up under extreme temperature variations, continuous exposure to abrasive dirt and dust, and against surge pressures which may fluctuate to as much as 50,000 psi.

The exclusive Roto-Mold process makes possible precision "O" rings—physically better—free from foreign inclusions and flash. Another plus is scheduled deliveries at maximum economy.

No matter what your sealing problem may be—call on LINEAR or one of its agents for engineering assistance—and be sure to specify LINEAR Roto-Mold "O" Rings.

"PERFECTION IN RUBBER"

LINEAR

LINEAR, Inc., STATE ROAD & LEVICK ST., PHILA. 35, PA.

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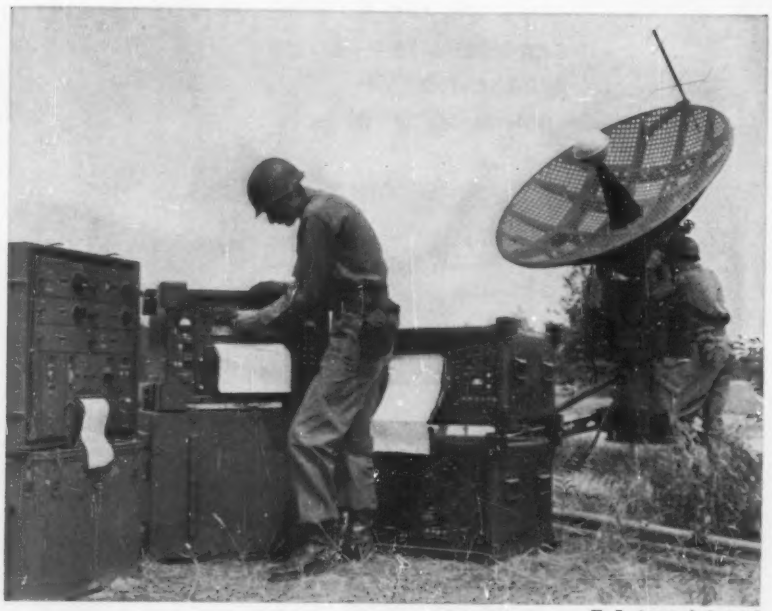
MACHINE DESIGN

ENGINEERING NEWS



U. S. Army photograph

AUTOMATIC WEATHERMAN interprets high-altitude reports from 3-lb radiosonde carried aloft by balloon. As dish-shaped antenna automatically tracks balloon, computers print out vital pressure, humidity, temperature, and wind readings. Developed by the U. S. Army Signal Engineering Laboratories, the computing receiver observes shifting winds of the upper atmosphere, vital in aiming long-range artillery and missiles accurately; instantly relays data for accurate forecasts.

Bubbles in Metals Aid Detection of Fatigue Cracks

Interesting Observation Leads to Specific Studies

WASHINGTON — An interesting observation has led to a technique that promises to be of value in studying the effect of surface reactions on metal fatigue and may prove practical in the early detection of fatigue cracks.

Motion pictures, taken at the National Bureau of Standards, of a fatigue fracture in an aluminum alloy had shown materials being extruded from the cracks in surprisingly large amounts, according to the size of the cracks. In an attempt to obtain some of this material for identification, an NBS worker applied a piece of transparent, pressure-sensitive tape to the surface of a torsion fatigue specimen. Earlier, fatigue cracks had been induced in the metal by several thousand cycles of reversed stress. When the specimen was stressed for an added thousand cycles, small bubbles formed under the tape.

A series of investigations disclosed that bubbles formed as soon as detectable cracks were present. Even when the cracks were so small they could be seen only with a microscope under special lighting, the bubbles were large enough to be seen readily with the naked eye. For this reason, it appears that this observational technique may be used to detect the onset of fatigue cracking.

Apparently, the bubbles can be produced with some metals and not with others. Very strong tendency to produce bubbles was observed with aluminum alloys. No bubbles at all were observed when brass and zinc were stressed.

Which Way Research? Admiral Pictures Rich Rewards

Naval Pure Research Uncovers Vast Fields, Plans New Ones

FORT WAYNE, IND.—One problem of explaining the value of basic research is that it is impossible to predict exactly what will come of a given study. Rear Admiral Rawson Bennett, Chief of Naval Research, in a recent address before the AIEE, pictured results that have had far broader application than naval or military use.

He cited a research program started a few years ago by the Navy to develop a simpler aircraft panel to replace the numerous dials and gages a pilot must now watch constantly. Navy research psychologists recommended a picture display of information.

"The first model of this new instrument system," said the admiral, "using flat plate television tubes together with a small compact computer to generate the required data, has already been flight tested on a military aircraft. It is easy to see the potentialities not only for future flight around the country, but also for space navigation. In addition, a byproduct of this system may well revolutionize your home television set. To make the tube transparent, a special transparent phosphor or film was developed by the Naval Research Laboratory to replace the powdered opaque phosphor now used to coat current commercial tubes. . . . The new transparent film can also provide a simpler, more efficient color TV tube and is expected to lead to the development of three-dimensional television viewing."

He told of Navy research findings in skin grafts, and its work as a major participant in the International Physical Year, which includes studies of solar radiation, cosmic rays, and the ionosphere as well as explorations in the Arctic and Antarctic.

Admiral Bennett then turned to a coming project. "Plans are now

...Fluid Power news

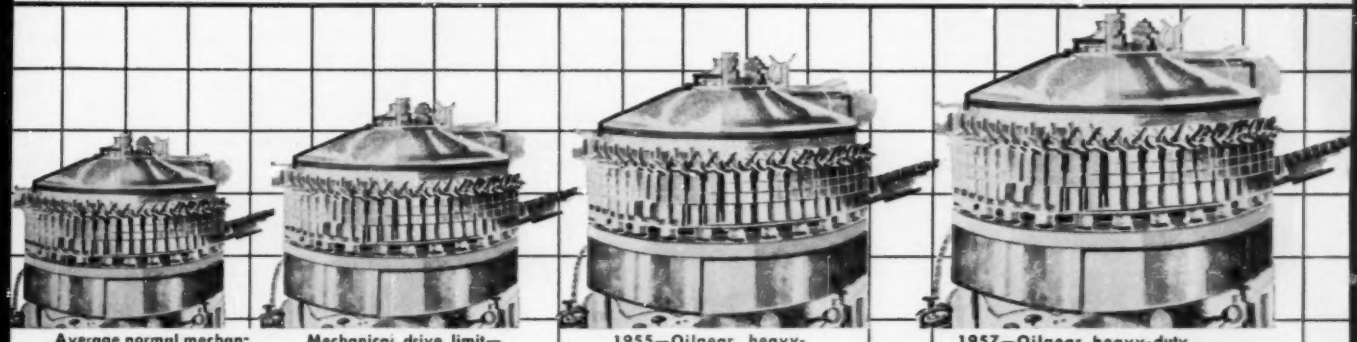
REPORT No. 11,301
HYTAC IMPROVES FILL-CLOSE PRODUCTION

From Oilgear Application-Engineering Files

HOW OILGEAR HYTAC DRIVES IMPROVE FILLER-CLOSER PERFORMANCE—TRIPLE OUTPUT

CUSTOMER: *A Large Food Machinery Manufacturer (Name withheld by request)*

DATA: This manufacturer called upon Oilgear to help solve the problem of producing a filling and closing machine that would exceed the mechanical drive limitations reached when the fill-close rate was increased from 150 to 360 12-oz cans per minute. *Summary of User Requests:* A fill-close rate of at least 425 12-oz cans per minute; accelerate to half speed in 2 seconds—to full speed in 5 seconds without jerky, jack rabbit starts that strain the equipment; reduce spillage and "deadheads"; decelerate to stop in 0.4 seconds; reduce costly losses due to under or overfilling; change speed instantly, easily—with remote control preferred: accurately hold any selected speed regardless of load or electric power variations—viscosity changes; impervious to daily sanitary washdowns; provide trouble-free, low-maintenance, continuous operation.



Average normal mechanical drive—150 12-oz cans per minute.

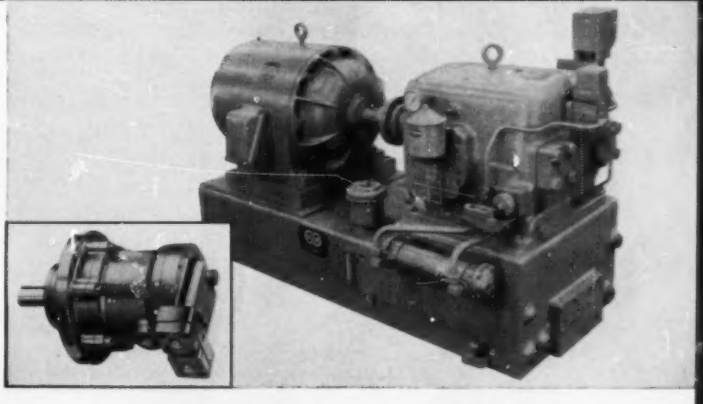
Mechanical drive limit—360 12-oz cans per minute.

1955—Oilgear heavy-duty, Size 20, Any-Speed HYTAC drive—to 600 12-oz cans per minute with improved performance.

1957—Oilgear heavy-duty, Size 35, Any-Speed HYTAC drive—to 1200 12-oz cans per minute with improved performance.

OILGEAR SOLUTION #1 (1955) Oilgear heavy-duty, Size 20, Any-Speed HYTAC (hydraulic tachometer) drives provided the first step in meeting user requests. These drives on a 6-spindle closer and 60-spout filler smoothly accelerated to full speed in 2 seconds—decelerated to stop in 0.2 seconds; a new, high fill-close rate—to 600 12-oz cans per minute without machine redesign; held *any* preselected speed within ± 0.5% regardless of load, electric power variations or viscosity changes—assuring uniform fill; reduced spillage and conveyor jams. Oilgear heavy-duty HYTAC simplified machine design and reduced maintenance by eliminating slip clutches and electric brakes—and by providing hydraulic cushioning; hydro-dynamic braking; automatic, positive protection against starting and running overloads. Remote, space-saving pump and motor location and completely sealed, leak-tight system provided protection to daily, sanitary washdowns. Users liked this improved performance and speed . . . over 50 similar installations have been made. Some users, however, continued to request higher production rates—with all of HYTAC's advantages.

OILGEAR SOLUTION #2 (1957) Due to the proven ability of Oilgear application-engineered, heavy-duty, drive and control systems to help meet user demands, this manufacturer naturally turned to Oilgear for further engineering teamwork in meeting new, greater production requirements. *RESULT*—new, higher production filling-closing machines that TRIPLE original mechanical drive output—to 1200 12-oz cans per minute with all the same desirable features outlined in the previous installations. One important addition has been made . . . new user satisfaction.



This is the newest Oilgear Power-Pak for filler-closers—Oilgear heavy-duty, Size 35 HYTAC drive components. Unit can be remotely mounted and remotely controlled for new performance, new production speed, new accuracy.

Here is but one reason and proof why designers and builders of machinery turn to Oilgear . . . why users recognize and trust the name . . . why more and more this phrase is heard, "For the lowest cost per year—it's Oilgear!"

For practical solutions to YOUR linear or rotary drive and control problems, call the factory-trained Oilgear application-engineer in your vicinity. Or write, stating your specific requirements, directly to

THE OILGEAR COMPANY

Application-Engineered Fluid Power Systems

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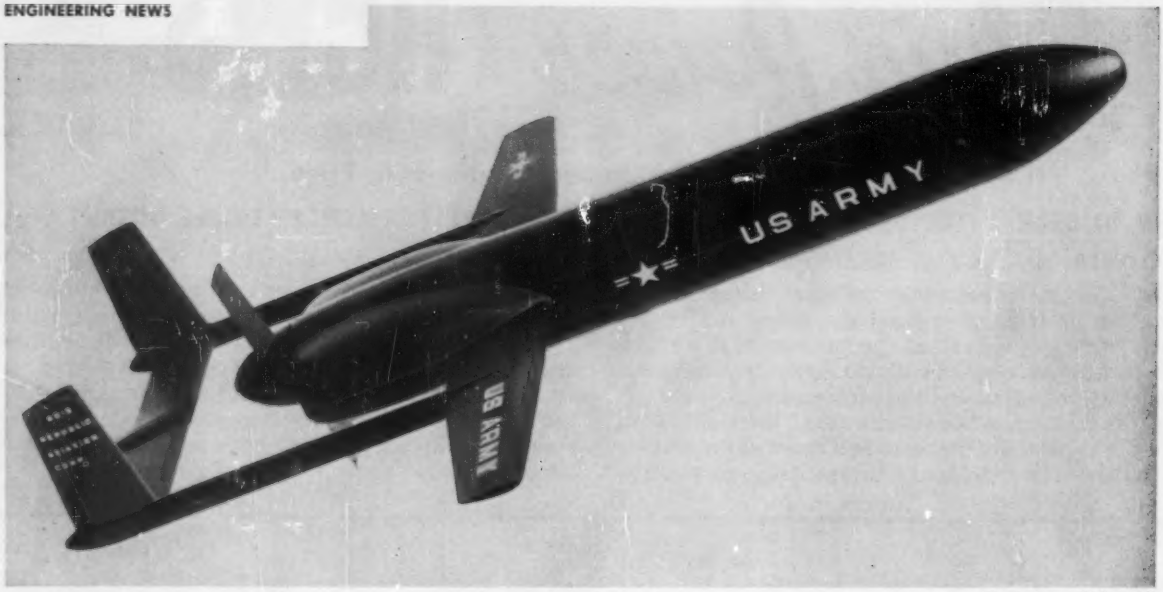


U. S. Army photograph

HIGH SPY for the Army, equipped with the most advanced surveillance equipment, is Republic's SD-3 unmanned drone. Interchangeable nose units permit use of radar, photographic, or infrared sensory devices. The all-weather system is launched by jet-assisted take-off, can be recovered, may have turboprop engine.

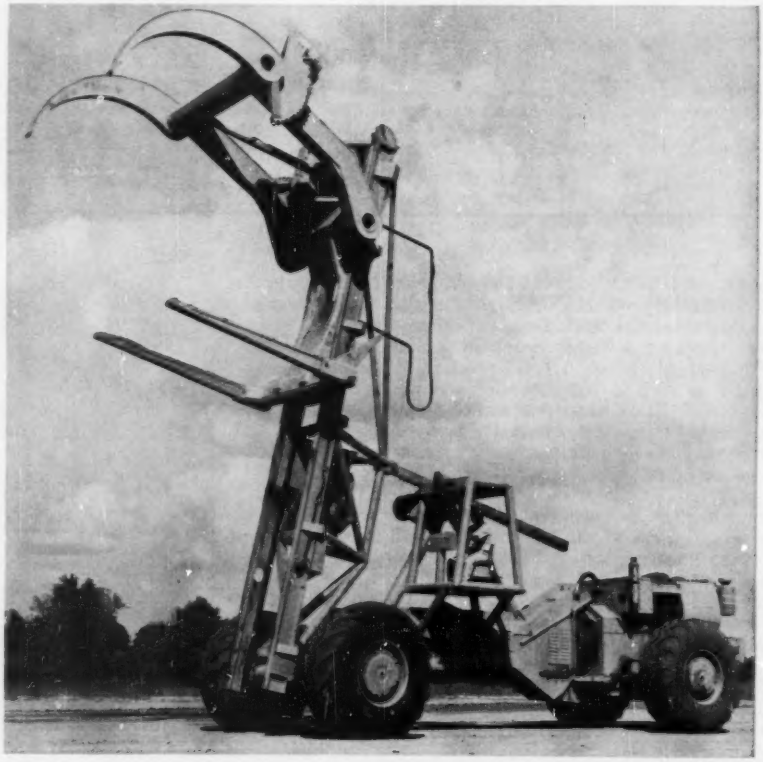
being made to send up in a few years telescopes attached to a television camera that will be controlled from the ground and will transmit live pictures of objects in the sky. The scientists in the project regard the balloon-borne telescope as a stepping stone to the satellite observatory, which will have an even larger telescope attached to a TV camera."

Preflight Test Equipment Checks Gun-Aiming System

Interceptor's Armament Control Checked in Three Minutes

PITTSBURGH—Preflight test equipment weighing less than 15 lb checks the accuracy of a Navy interceptor's weapons system, without actual firing, in less than three minutes. Developed by Westinghouse Electric Corp., the test equipment is designed for installation as an integral part of the plane's electronic gun-aiming system.

Use of the test equipment, according to company spokesmen, is not limited to grounded aircraft. A pilot will be able to perform these same tests while in flight. This will eliminate the possibility of a plane flying into combat with



JOINTED TUSKS can methodically unload logs from 100-ton trucks by taking 22-ton bites from the top. Manufactured by R. G. LeTourneau Inc., the Goliath functions as a giant hand. It can pick up the "peaker" log from a truck, roll it back onto the forks, and then move in for more until fully loaded with its rated 22-ton capacity. At one west coast mill where log stacker is used, easily damaged redwood is gently and safely unloaded from trucks, then sorted and decked. Tong-hole wood damage is cut.

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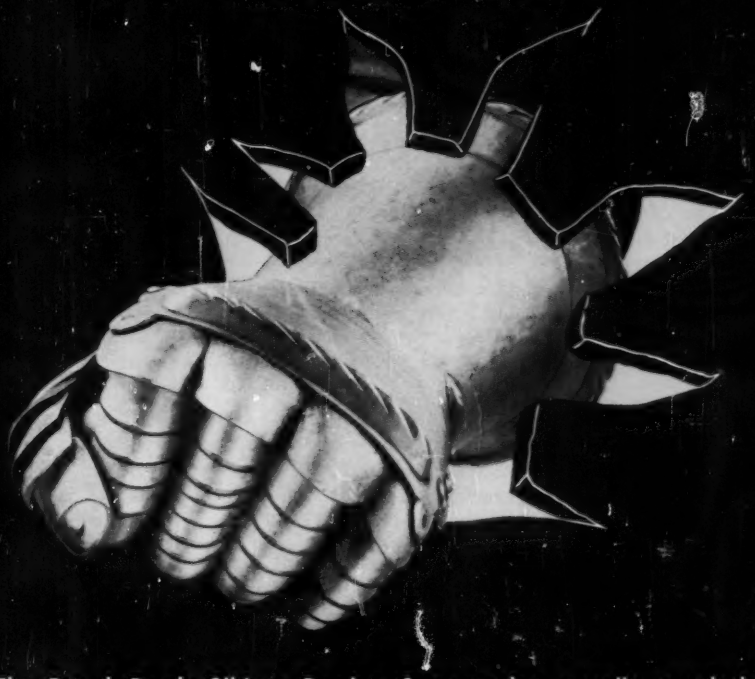
IRON CURTAIN SMASHED!

"NEWS ITEM NO. 1 — 1958"



The Bound Brook Oil-Less Bearing Company has proudly smashed through the iron curtain of skepticism surrounding the use of sintered iron bearings. Although Bound Brook's POWDIRON has long been hemmed in by indifference and prejudice, this LOW-COST, tough performer has higher strength than bronze, excellent finish, and bearing characteristics adequate for many applications. Find out how POWDIRON can smash your bearing costs and strength problems to-day.

BOUND BROOK

BOUND BROOK OIL-LESS BEARING CO., EST. 1883, BOUND BROOK, N. J.

Pioneer in

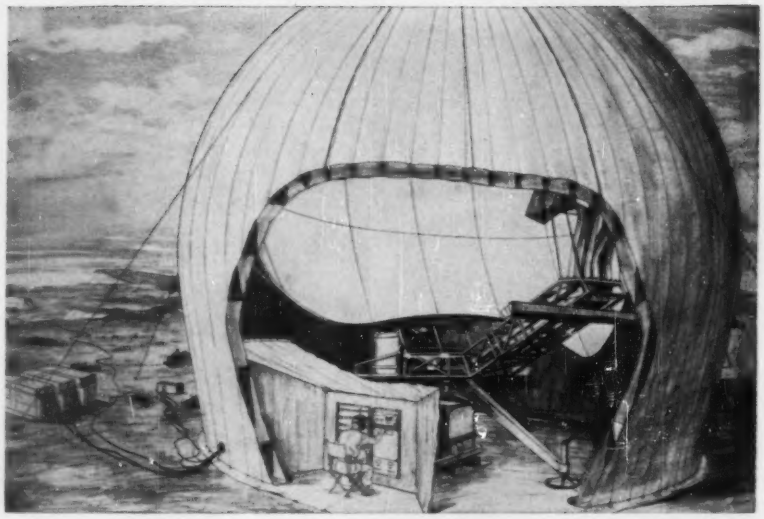
POWDER METALLURGY BEARINGS + PARTS

our 75TH year

its armament control system in need of adjustment.

The six-step checkout process involves feeding artificial signals to simulate combat conditions into the system under test. The test equipment presents a realistic problem into the gun-aiming system. This is done in such a way that the pilot or technician can tell whether different components are working properly in interpreting signals that appear on the radar cathode-ray tube.

Increased use of aircraft is cited as a particular advantage of the development. The faster and more frequent tests will reduce the number of planes grounded for adjustment of the control system and thus increase the number of combat-ready interceptors.



Portable radar antenna shelter for the Marines' new tactical early warning (TEW) system, resembles the permanent radomes used on the famous DEW line. This inflatable structure can be heated or cooled for use in any climate. Signals picked up by rotating antenna in the radome are passed through radome console and fed to a combat-interceptor control nearby.

Portable Early Warning System Will Supplement DEW Line

WASHINGTON—A tactical counterpart to the permanent DEW line radar defense is being developed for the Marine Corps by Sperry Gyroscope Co. The new, portable system is designed to meet the Marines' particular requirements for helicopter-transportable equipment, adaptable to rapidly changing tactical situations.

Operational units of the new tactical early warning (TEW) system are one-fourth the size and weight of conventional installations, yet the system will provide three-dimensional data on aircraft and missiles flying at extreme range. A compact V-beam antenna, rotating in an inflatable radome structure, enables operators to redetermine the range, azimuth, and altitude of all enemy targets once every 10 seconds.

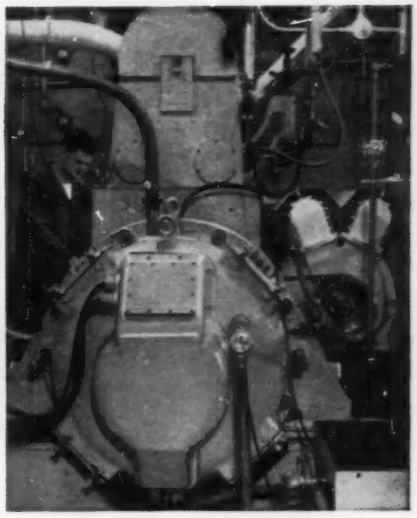
Component parts of the system are transported on self-contained pallets, and the entire unit, including combat interceptor control, antenna system, and inflatable radome can be erected in 2 hours by an 18-man crew.

U.S.S.R. photograph

RUSSIA'S ATOMIC LENIN, the world's biggest icebreaker and first nuclear-powered surface ship, will soon duplicate the appearance of this scale model. Designed to break through ice more than 6 ft thick, the new vessel is 435 ft long, has a beam of 88 ft, and displaces 16,000 tons. Her three electric motors develop 44,000 hp and draw 30,000 kw of electrical power from her nuclear-steam-electrical system. Cruising speed is reportedly 22 knots. Equipped with plush, air-conditioned quarters for her crew, the Lenin will carry a high ratio of engineers to ordinary seamen. Comparable U. S. ship is currently before Congress.

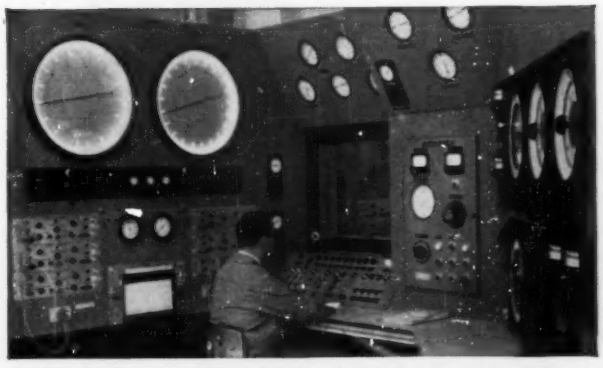
ND FACTS

New Departure makes a complete line of jet engine, auxiliary turbine, and accessory bearings for the aircraft industry.



Test stand for running jet engine ball bearings at high speeds, high temperatures under heavily loaded conditions.

RESEARCH NEVER STOPS!



Instrumentation and control console for test stand shown above, for testing full-scale mainshaft ball bearings.

Tomorrow's needs are today's concern at the aircraft ball bearing research facilities at New Departure. For, the future development of the ball bearing will be closely identified with future engine design trends. This means New Departure spares no effort in developing bearings to operate at higher speeds, heavier loads, and under higher temperatures with good bearing-life predictability.

As always, New Departure keeps pace with changing conditions in the industry. For New Departure's design and fabrication processes for current high-speed, high-temperature, heavily loaded ball bearings are major factors in the successful operation of today's jet engines, as well as auxiliary turbines and accessories.

For aircraft and accessory bearings, send for **CATALOG ABC.**

For data on research progress for jet engine bearings, send for **REPRINT JEB.**

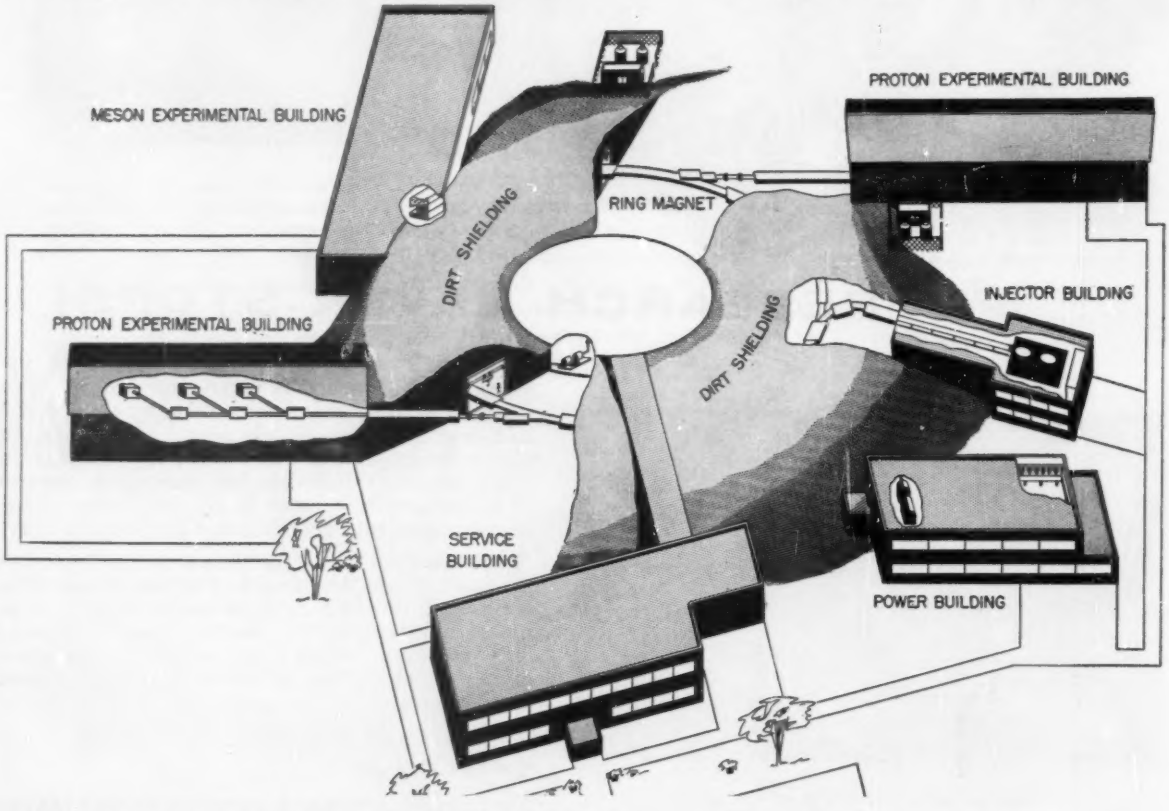
1908–1958 GM FORWARD FROM FIFTY

ND NEW DEPARTURE

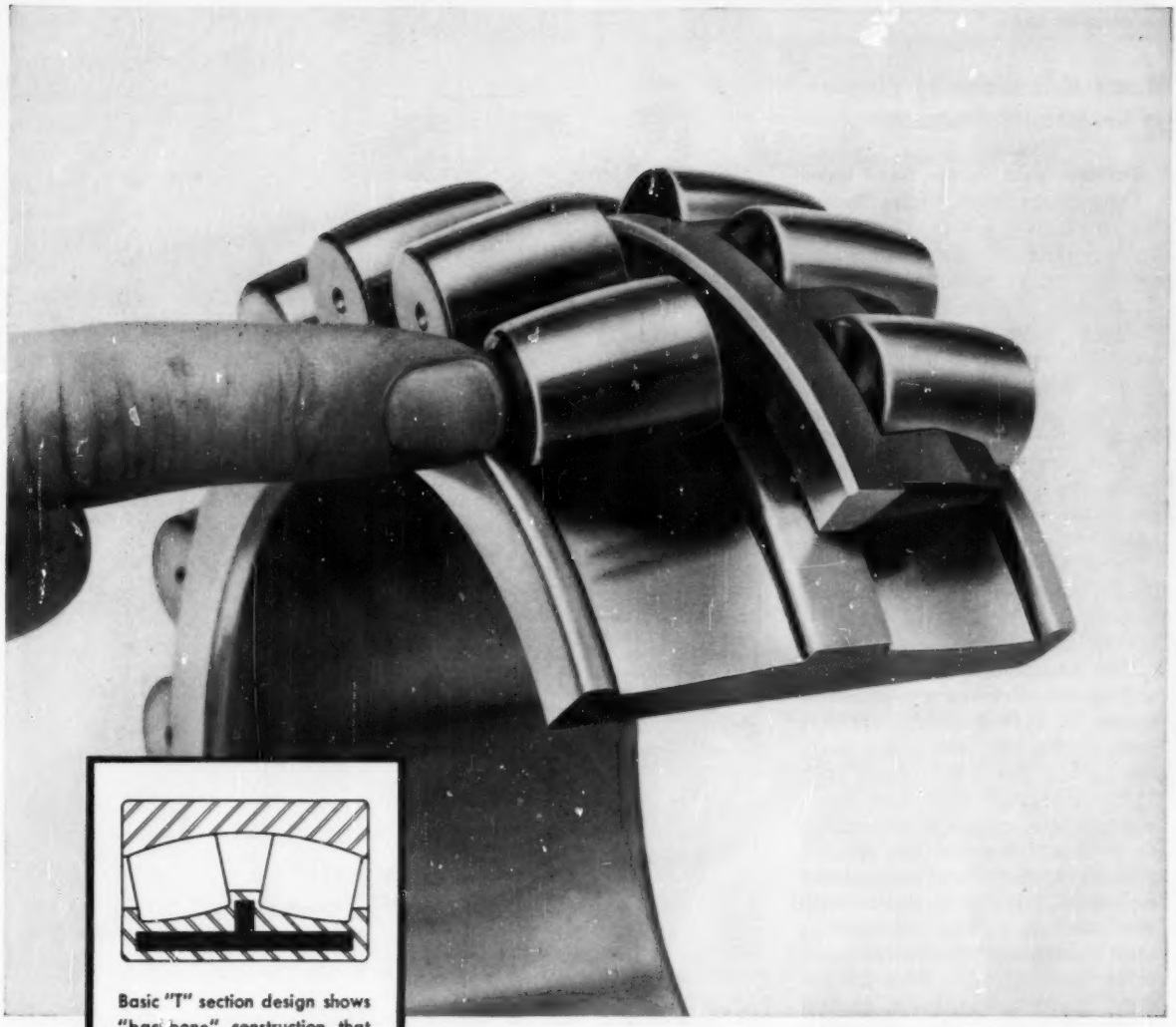
DIVISION OF GENERAL MOTORS, BRISTOL, CONN.

NOTHING ROLLS LIKE A BALL

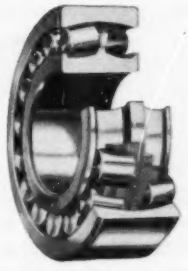
RAMBLER AMERICAN is added to American Motors' lineup for 1958 after being discontinued for three years. Built on a 100-in. wheelbase, the '58 American is offered in a Deluxe or Super 5-passenger, two-door sedan. A Deluxe business coupe is available to fleet buyers. Body dimensions include, overall length, 178 in.; width, 73 in.; height, 57 in., and weight, 2500 lb. Powerplant is a 6-cyl, L-head engine that provides 90 hp at 3800 rpm. Compression ratio is 8 to 1; displacement, 195.6 cu in. Borg-Warner automatic transmission or overdrive are optionally available. With overdrive, gas mileage is said to reach 35 mpg. According to AM, their American will retain "styling stability", and for further economy comes equipped with an owner's do-it-yourself handbook for making minor repairs and adjustments.



DETAILED DESIGN START for a 12.5 billion electron-volt synchrotron has been authorized by the Atomic Energy Commission. Cost of the facility is estimated at $27 million. The AEC has made available $1.5 million for initial studies. Plans call for facilities to be located at Argonne National Laboratory, 25 miles southwest of Chicago. Argonne engineers report the new machine will produce greater numbers of accelerated particles than any other of the multibillion electron-volt accelerators now in operation or under construction anywhere in the world. The sketch shows how proposed facilities for the synchrotron would appear if completed according to present plans. Hydrogen ions are made in injector building and speeded up to 50 million electron volts (62,000 mps) in linear accelerator. Protons are then shot into channel inside the ring magnet to travel around the 600-ft circumference circle 1.5 million times, a distance of 195,000 mi.; in one sec, are accelerated to final speed of 12.5 billion electron volts (185,000 mps). High-speed protons are then brought out of magnet and sent into proton or meson experimental area, where they smash atoms.



Basic "T" section design shows "backbone" construction that insures positive roller guidance and stability without skewing under all load conditions.



For roller stability...

there's nothing like "the bearing with the backbone"

The only *positive* way to guide rollers is by an integral center guide flange—backbone of the *Torrington* Spherical Roller Bearing. No floating ring can match it for stability under heavy radial and thrust loads.

This "bearing with the backbone" insures true rolling motion . . . prevents stress concentration . . . means minimum friction. It makes possible open-end cage design, too, with no shrouds to impede circulation of lubricant to bearing contact surfaces. There is less heating and more positive lubrication.

The integral center guide flange is adapted from the same principle used in the design of Torrington Tapered Roller Bearings. This refinement is typical of Torrington's uncompromising engineering that assures you the ultimate in bearing performance. **The Torrington Company, South Bend 21, Ind.—and Torrington, Conn.**

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Wants Maintainability Clauses In Government Contracts

Defense Maintenance Head Says Contractors Need Finite Terms

LOS ANGELES—Maintainability will be specified in military contracts, if one Dept. of Defense official has his way. "As unwelcome as this conviction may be to some, we will obtain genuine maintainability, consistently, only when what we need is reduced to finite terms and is incorporated into specifications against which procurement contracts are awarded," said Maintenance Engineering Director Edward J. Engoron before the Electronic Industries Association Conference held recently at the University of Southern Calif.

"We are maintaining a weapons and equipment inventory valued in excess of $110 billion," said Engoron. "To do this, we have, throughout the world, more than 21,000 buildings of various kinds comprising in excess of 250 million sq ft in which more than 600,000 military and civilian maintenance technicians do their daily work. We have had to buy and have on hand maintenance spares and spare parts that cost more than $20 billion. On an annual basis, maintenance of our weapons and equipment costs the Dept. of Defense more than $7 billion—or $20 million each day.

Maintenance is not what it should be, he continued. True effectiveness means that an item of military equipment is ready to do its job at the time required. Too many weapons in the hands of maintenance people mean they are not out in the field.

Maintainability is a design parameter, according to Mr. Engoron. "A general maintainability concept can be developed during the preliminary design phase for new equipment. In any event, specific maintainability characteristics must be incorporated not later than during the prototype design phase."

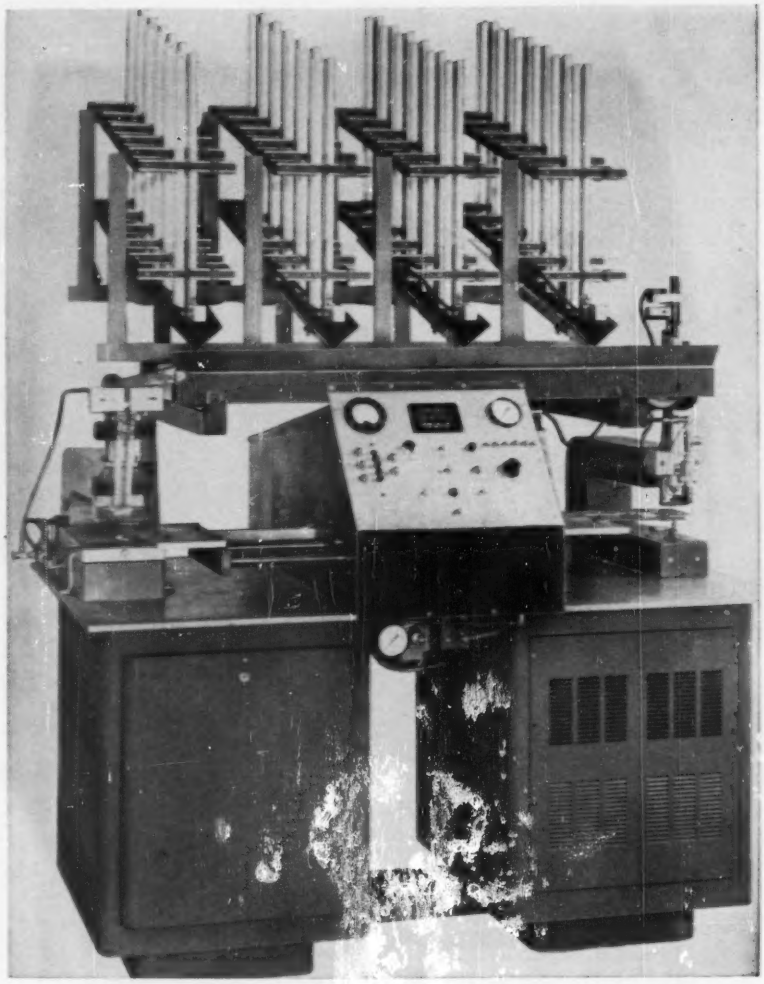
The Maintenance Director singled out the next generation of designers as "the most valuable asset" for assuring maintainability. Besides "education by exposure," he urged they be taught maintainability as part of their engineering curricula and that post graduate work in the field should be encouraged.

Mr. Engoron said that since maintainability concepts must find acceptance by design engineers, "the maintainability group should be manned primarily with design engineers who have had field service experience."

He downplayed accessibility in itself as a sufficient measure for maintainability. While maintainability must include access to trouble sources, the heart of the problem is design of the equipment proper.

Speaking of the human element in maintainability, Engoron discussed technicians' limitations. "Practically all of our direct support maintenance — organizational and field level—is accomplished by military technicians—some 600,000 of them. Only 55 out of each 100 of these technicians have graduated from high school. Slightly less than three out of each 100 have graduated from college. This is the formal educational level for which maintainability must be designed."

The facts are that weapon selection depends on reliable operation and effective maintenance.



ELECTRONICS, MAJOR CONTRIBUTOR to automating other industries, is now looking to its own needs. With what is called complete automatic operation, new device produced by Design Tool Corp. responds to punched tape. It precisely positions circuit boards, drills holes, selects up to 24 different components, and inserts components, eyelets, and terminal pins. Manufacturer claims device is self-sufficient unit; any firm entering electronics need not disrupt the production line of present work.

FIRST FLIGHT of the Atlas ICBM in June, 1957, is pictured shortly before the big missile veered off course and was destroyed. First successful flight — third try — was in December when the weapon flew a prescribed course of 500 miles. Visible jet streams in this recently released photo are apparently from the missile's two 135,000-lb thrust booster motors. A third liquid-propellant sustaining motor provides 100,000 lb thrust.

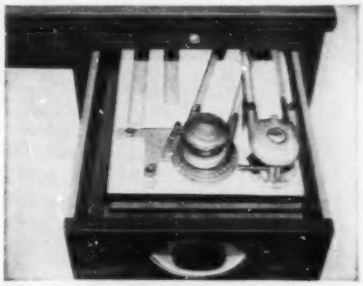
DRAFTING TRENDS

Chief Draftsman W. P. Nickels of Tennessee Gas Transmission Company (Houston, Texas) at work with his portable "Desk Topper"

Portable drafting unit sets up in two minutes

A handy drafting unit with the precision of a full-size drafting machine is now available to engineers who need portable facilities. Called "Desk Topper," the package-size unit can travel along with you or slip away in an office drawer. All essentials are included: drafting machine, set of scales, folding board, storage container for tools, and paper dispenser.

The "Desk Topper" sets up quickly (2 minutes) on any desk or table—at home, in the office, hotel room or studio.



The complete "Desk Topper" hides away quickly in any standard desk drawer or in the sturdy carrying carton. (Handsome luggage case is available at extra cost.)

The unit comes packed in a lightweight carrying carton for easy portability. For engineers who use the board only occasionally, the entire unit fits into any standard desk drawer.

Manufactured by Universal Drafting Machine Corp., "Desk Topper" has the professional features of their large "Boardmaster" machine—360° protractor, automatic 15° indexing, full line base selector, double 10′ vernier and clamp, elbow height adjustment, screw anchor, enclosed band and pulley arms, built-in brakes for 10° board slope.

The smooth linoleum surface board measures 21″ x 23½″ when open, 21″ x 11¾″ when closed. Normal drawing capacity is 17″ x 22″, or 24″ x 36″ when mounted to a larger board. The legs with rubber feet fold up automatically, provide a 10° slope in use.

The "Desk Topper" scales are another excellent feature. Self-locking and self-aligning, they eliminate two common causes of drafting machine inaccuracy —loose chucking, and errors in right angle alignment.

Further information on "Desk Topper" is available from the Reader Service Division of the Frederick Post Company, 3652 N. Avondale Avenue, Chicago 18.

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Circle 410 on Page 19

We welcome inquiries
We are specialists in the custom-building of the types of gears shown here. We make them in quantity to your specifications.
Manufacturers who want that kind of wide specialization—and who are looking for a company that can serve as a "gear department" are indeed invited to write or phone. The answer will be prompt.
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GEAR-MAKERS TO LEADING MANUFACTURERS

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Reader Information Service

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USE A YELLOW CARD *for More Information . . .*

CIRCLE ITEM NUMBERS—Throughout the magazine, each advertisement carriers an Item Number for use in requesting further information. All product descriptions, announcements and Helpful Literature items are also numbered, and for greater convenience are indexed below by Item Numbers.

EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

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408	433	458	483	508	533	558	583	608	633	658	683	708	733	758
409	434	459	484	509	534	559	584	609	634	659	684	709	734	759
410	435	460	485	510	535	560	585	610	635	660	685	710	735	760
411	436	461	486	511	536	561	586	611	636	661	686	711	736	761
412	437	462	487	512	537	562	587	612	637	662	687	712	737	762
413	438	463	488	513	538	563	588	613	638	663	688	713	738	763
414	439	464	489	514	539	564	589	614	639	664	689	714	739	764
415	440	465	490	515	540	565	590	615	640	665	690	715	740	765
416	441	466	491	516	541	566	591	616	641	666	691	716	741	766
417	442	467	492	517	542	567	592	617	642	667	692	717	742	767
418	443	468	493	518	543	568	593	618	643	668	693	718	743	768
419	444	469	494	519	544	569	594	619	644	669	694	719	744	769
420	445	470	495	520	545	570	595	620	645	670	695	720	745	770
421	446	471	496	521	546	571	596	621	646	671	696	721	746	771
422	447	472	497	522	547	572	597	622	647	672	697	722	747	772
423	448	473	498	523	548	573	598	623	648	673	698	723	748	773
424	449	474	499	524	549	574	599	624	649	674	699	724	749	774
425	450	475	500	525	550	575	600	625	650	675	700	725	750	775

SEND COPIES OF FOLLOWING ARTICLES IN THIS ISSUE

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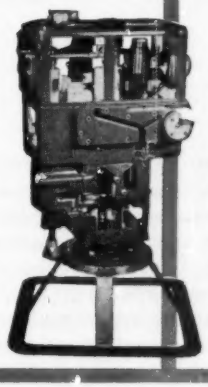
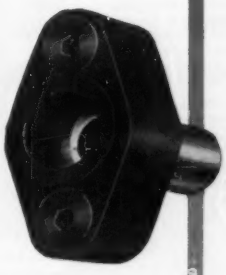
5 practical ways to "streamline"

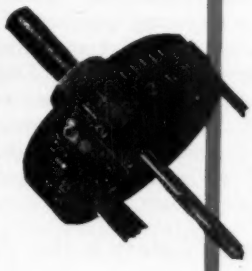
...without sacrificing fastening strength



1. Counterbored holes are the simplest approach to flush surfaces using standard socket cap screws. The advantage of specifying genuine Allen O Head Cap Screws is the greater strength of Allenoy steel... you can use smaller sizes for closer spacing and reduced weight. Call on Allen, too, for *very large* socket-head, precision cap screws — up to 2½ inch diameter.

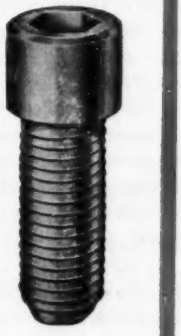


2. Countersinking enables you to get absolutely smooth external surfaces using Allen O Flat Head Cap Screws. Allen O Cap Screws feature the exclusive Leader Point which makes screw starting easier and guards against thread damage.



3. Button Head Cap Screws produce snag-free unbroken surfaces where countersinking is impractical. Button-head hex sockets are necessarily shallow. In genuine Allen O Button-Head Cap Screws, sockets are cold forged without broaching, in extra strength Allenoy steel... essential protection against stripping the sockets under high torque pressure.

4. A ready made hole tapped in forged steel solves many a design problem. It's called the Allenut. It can be anchored in soft material to assure durable threading, or recessed to permit tightening with an Allen Hex Key.



5. Bright finish, or rust and corrosion resistance call for Allen O Stainless Steel Cap Screws. They are standard stocked items (both NF & NC threads) readily available in a wide range of sizes from Allen Distributors.

YOUR ALLEN DISTRIBUTOR can give you practical help and swift service. For complete information on any technical fastening problem, write our engineering department direct.

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Hartford 2, Connecticut, U.S.A.

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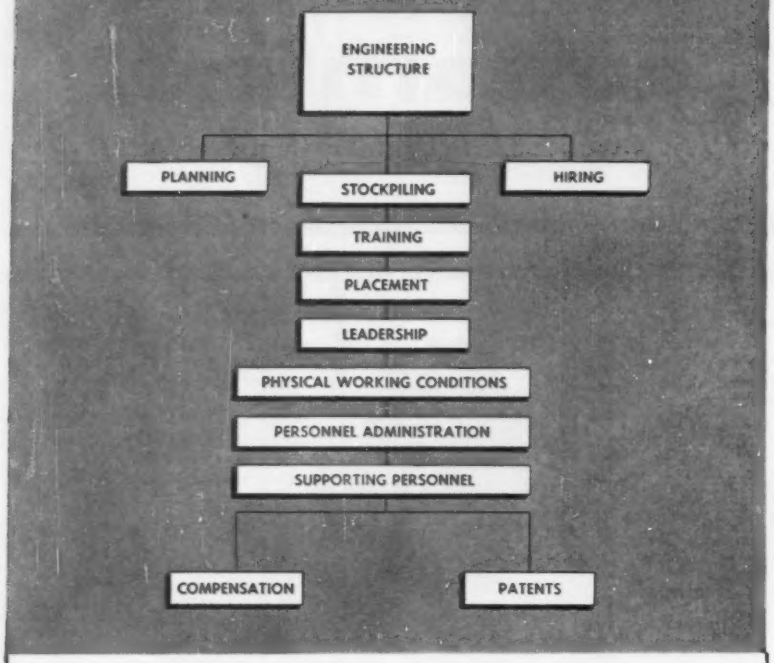
ORGANIZING for PRODUCTIVITY



DESPITE ANY DISAGREEMENT over the size and extent of the engineering shortage, effective use of engineering personnel has become vital. Industrial, labor, governmental, and educational organizations have shown serious concern. Several questions pose a crucial problem for engineers and engineering management:

- **What is industry doing with its engineers?**
- **What might be done better?**
- **How can it be done?**

The research report* on which this series of articles is based was designed to answer just these questions. Information was obtained from a cross section of industrial corporations located in all parts of the country, from management consulting firms, governmental agencies, and others. Since long-term outlook is for greater demands on engineering and fewer engineers to answer them, prime focus in the report is on how industry is using its engineers.

The report was prepared, and the comprehensive survey conducted, by a graduate group over a period of seven months at the direction of Prof. G. F. Doriot of the Graduate School of Business Administration at Harvard University. George A. von Peterffy was leader of the group, which included Robert E. S. Arndt, Jack L. Clark, Charles W. Coker Jr., William B. Ellis Jr., George C. Hibben, C. Bayard Johnson Jr., Silas Keehn, and Robert M. Prioleau.

Each part of the series will deal with what investigation disclosed to be a major area affecting the productivity of engineers. Future articles will discuss planning, hiring, stockpiling, training, placement, leadership, supporting personnel, physical working conditions, personnel administration, compensation, and patents.

*_Engineering Manpower_, a report available from Engineering Management Reports, P. O. Box 161, Cambridge 38, Mass. Price: $18.50

The

THE TWO or three-man engineering department common at the turn of the century has in many industries grown into groups of hundreds, and sometimes thousands of men. With growth, it has become increasingly necessary to readjust the position of the engineering department in the company and to shift the overall organizational structure of the company as well.

In the relationship of organization to engineering productivity, three distinct levels of consideration become apparent: 1. Engineering's place in the company organization. 2. Internal organization of the department. 3. Organization of the basic working group.

Engineering's place in the company organization

An organization diagram is much easier to evaluate than the actual internal relationships between its parts. Good co-ordination between the engineering department and other departments has become extremely important. And the internal relationships are the important ones. Unless engineering manpower is applied to and expended on projects that fit the aims of the company as a whole, potential productivity will be wasted.

A large electronics firm, failing to see this need, decentralized plants throughout cities in the East, but concentrated its engi-

Engineering Structure Today

neering force in one city. Every time trouble developed in one of the plants, engineers were rushed out to solve the problem. Finally, the situation was corrected by decentralizing the engineering force.

Some engineering executives have expressed concern that the other parts of management either didn't understand what the engineering group was doing or really didn't care. This lack of appreciation is particularly prevalent in the assigning of projects to many engineering departments. Priorities are often assigned in a slipshod way, completion dates sometimes suddenly advanced, and projects added or dropped from the schedule with a minimum of notice. As a result, many chief engineers apparently lead a rather chaotic life as they try to anticipate management's next move. When this chaotic atmosphere pervades the engineering organization, productivity potential is wasted in projects which are either canceled or poorly scheduled. Great damage to morale usually results also.

Organization within the engineering department

Two basic approaches or a combination of these have been adopted by most engineering departments. One is the projects method, wherein a group of engineers carries out all phases of a single project. The other is the systems method, wherein each group of engineers is assigned to a specific phase of many projects. When these methods are combined, systems groups work under the supervision, or through the co-ordination, of a project engineer.

In the projects approach, companies assign engineers in groups to specific plans or projects. These engineers report directly to a technical and administrative engineer in charge of the project. This approach seems especially adaptable to companies that have a number of smaller projects that can be worked on by engineers with broad experience.

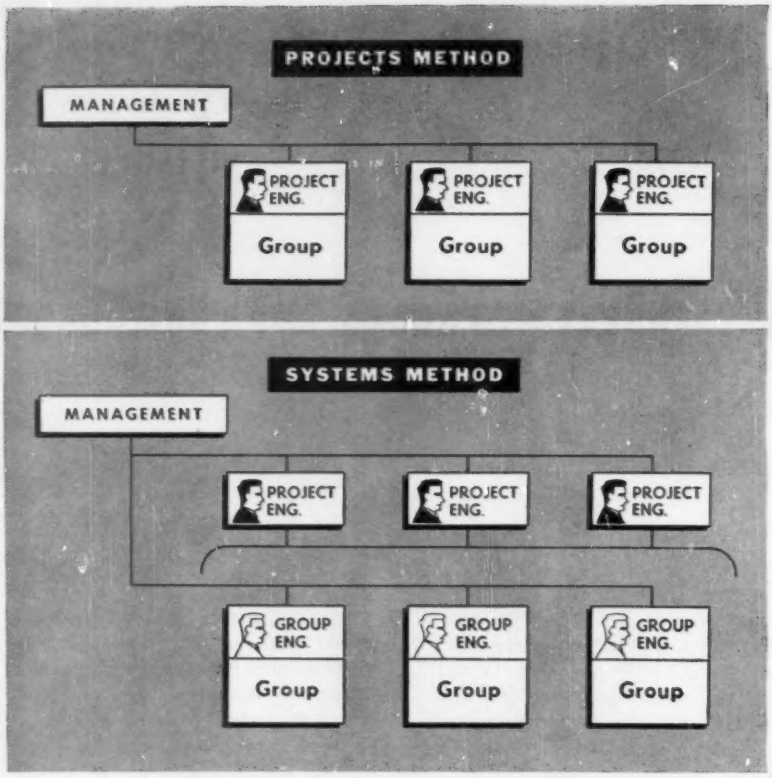
Engineers tend to prefer a project system. An important advantage is the breadth of experience gained by them by working on different phases of problems over a

Checkpoints for Engineering Management

- ☑ 1. Have changes in your organization kept pace with growing dependence on engineering?
- ☑ 2. Are relationships of engineering to other departments clearly defined?
- ☑ 3. Is your supervisory structure efficient?
- ☑ 4. Has your approach to engineering problems been set up with regard for efficiency and morale?
- ☑ 5. Are working groups well supervised . . . of optimum size?

number of years. By moving from project to project, the engineer is constantly meeting changing circumstances and has less chance of developing static concepts or becoming bored. Though the projects approach normally has a favorable effect on engineering morale, some companies reported that it also can have a drawback. The disruption of groups caused by physically redistributing men among other projects after completion of one project has occasionally resulted in severe problems. Another possible disadvantage is that some project engineers are apparently doing work which could be done by technicians or nontechnical personnel. A medium-sized tool company reported:

> • One man is entirely responsible for a project almost from its inception to its completion. He does the design work, writes specs for all the equipment, investigates potential suppliers, places orders, follows up orders, keeps account of all expenses and expected costs, and submits bimonthly reports to management on the progress of all the work. Though we realize his nontechnical workload is heavy, we feel that the job can be done faster and more effectively by having one man handle it all.



PROJECT versus SYSTEMS methods pit breadth of experience against efficiency of specialization. In projects method, engineers tend to handle all tasks under single line of authority and responsibility. In systems method, each specialized group works for group engineer, in conjunction with one or more project engineers. Here, line of authority and responsibility is split.

In the systems approach, there is more fragmentation of the engineering job. Rather than working on any one project as a whole, each group works on a specialized phase of all projects. Instead of working for a project engineer, they work under the cognizance of a group engineer who works in conjunction with the project engineer, who in turn is responsible for the whole project. Thus, both responsibility and authority are split, and co-ordination is sometimes difficult. It was found that the large, technically oriented companies with complex engineering work tended to use the systems approach.

One of the particular advantages of the systems approach is its efficiency. The profitable use of past experience is possible to a greater degree in the systems approach. Since the same group will always be dealing with the same types of problems, less time is wasted by delving into areas that have previously proved fruitless. Drawback to the systems approach is that although the man can become a highly skilled specialist, his overall experience becomes limited. An airframe manufacturer reports:

> • In general, our engineers are assigned to specialized design groups such as structures, hydraulics, landing gear, mechanical controls, electrical, etc. Some shifting of men from group to group is done to balance manpower requirements, but each group has the responsibility for design of its specialties on all airplane models.

In the combined approach, companies can merge the efficiency and specialization of the systems method with the line authority given the project engineer in a project approach. It is particularly noteworthy that the large aircraft companies seem to favor a combination approach. These companies, faced with extremely large-scale projects of a highly complex nature, feel that it is a necessity for the project leader to have the line authority necessary to maintain positive control over the progress of the project. One firm reported that each technical group is represented on a co-ordinating committee directed by the project engineer. A large rubber products company varies their approach. Their chief engineer wrote:

> • As to whether engineers are assigned to a project or to a given technical field depends a great deal upon the complexity of the problem. A straightforward engineering job that falls entirely within the experience of an individual engineer may be assigned completely to him. Frequently the elements of a problem are diverse and require the teamwork of a group of specialists.

The combination approach allows the particular systems groups to maintain their entity, thus preserving the structure of relationships within the group. Yet, by being assigned to a variety of projects over a period of time the individual engineer's experience may be broadened. The continuity of personnel within the group is an important aspect. Group leaders

have a greater opportunity to become familiar with the abilities of the men within the group. Thus they can more accurately match these abilities to the work.

Organization of the basic working group

In discussing the question of basic group structure with high level engineering supervisors, it was found that a very large number of them agreed that the working group was a basic consideration in determining engineering productivity. But this was the extent of agreement. Feelings about optimum group size, relationship with the supervisor, and similar aspects varied considerably. In general, management desires for small groups are often balked by the lack of good supervisors.

One airframe manufacturer has groups as large as 50 or 60, but would prefer smaller units if qualified supervisors were available. Another felt that a group with as few as five engineers was best since the group leader would have a better opportunity to know his men and work with them. The group size of another company contacted is determined by their working facilities. Small partitioned offices are used with five to eight engineers and a supervisor assigned to each office. The company found this group size and environment a very big improvement over the days when all their engineers were housed in one large room.

With regard to organization, the survey concludes that carrying out improvements, where indicated, should step up productivity of the engineering department. It should reduce costs, since records and written reports, which are almost invariably involved where work groups are large, can be reduced or eliminated. Reducing the size of large work groups has beneficial effects on the individual engineer as well. It usually serves to give him a sense of belonging, and permits greater stimulation by an effective supervisor.

Next article in this series will appear in the Jan. 23rd issue. It will include the planning of work objectives, scheduling of work, and handling of crash projects.

Recommendations for Management

1. Check Department Structure

With increase in size of the typical engineering organization, management is advised to check the internal structure of the engineering department. The absence of changes, when needed, has almost always been detrimental to engineering productivity.

2. Define Department Relationships

Clear definition of the relationships of the engineering department to the rest of the company means more than the organization chart shows. Engineers must know where they fit into the operations of the company and what is going on about them. Lacking such clear understanding, they will not function effectively. Other departments, conversely, must be well acquainted with what engineering is doing and can do, in order to make best combined effort.

3. Minimize Supervisory Levels

Growth of a company causes the number of supervisory levels between engineers and management to increase. The impact of vital information is often lost through a large number of supervisory layers. Much of the loss could be avoided by a conscious effort to keep the number of layers to a minimum. To improve information flow, personal communications through such devices as lunches and conferences with personnel in other departments and with top management are extremely valuable.

4. Examine Technical Approach

Internally, the use of the project or systems approach depends on the nature of the work. There are definite pitfalls to each. Under the project system, the need to shift men around causes difficulties. When groups are split up and men redistributed to other projects, friction may arise. To minimize discord, management must take care to maintain pressure so that engineers adjust to changes rapidly. In the project system, evaluation of the individual is difficult. Management must take pains to institute careful, systematic rating, or morale will suffer. Evaluation of the individual is easier under the systems approach, which tends to be more efficient, organizationally. However, to prevent boredom and mental stagnation of engineers, management is advised to rotate men periodically. Though this will impair short-range productivity, it will more than compensate in increased productivity over a period of time. It is up to management to develop a rotation plan suitable to the company.

5. Control Group Size

Management can improve productivity by setting the size of the working group. Generally, the tendency is that the smaller the size of the group, the easier its evaluation and control. However, group size should be reduced only if capable supervisors are available. Smaller groups under poor supervisors are generally less productive than larger groups under good supervisors. When good supervisors are not available, concentrated efforts should be made to develop capable people through training in leadership and supervision. Gradual reduction in the size of the work group can then be carried out.

Digital Computer Flies Plane From Takeoff to Touchdown

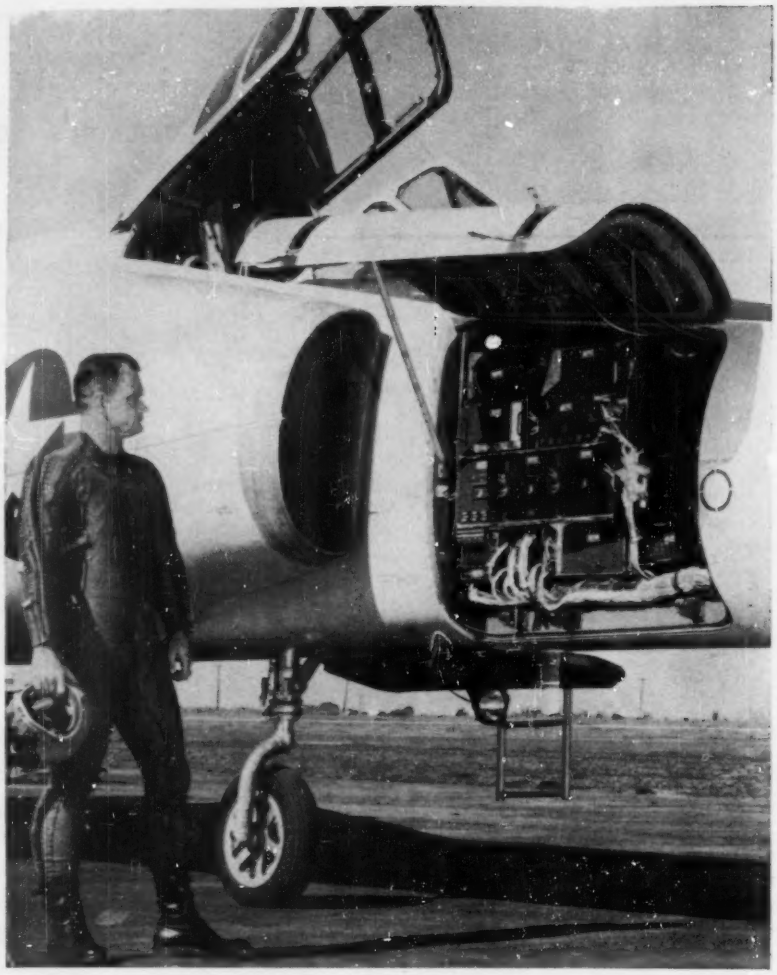
Now in Production, Unit Will Fly Interceptors

NEW YORK—The U. S. has an airborne, digital computer that can fly an Air Force jet interceptor through all phases of supersonic combat from takeoff to touchdown. Developed by Hughes Aircraft Co., the new computer reportedly digests 61 different types of information, reads out 30 types.

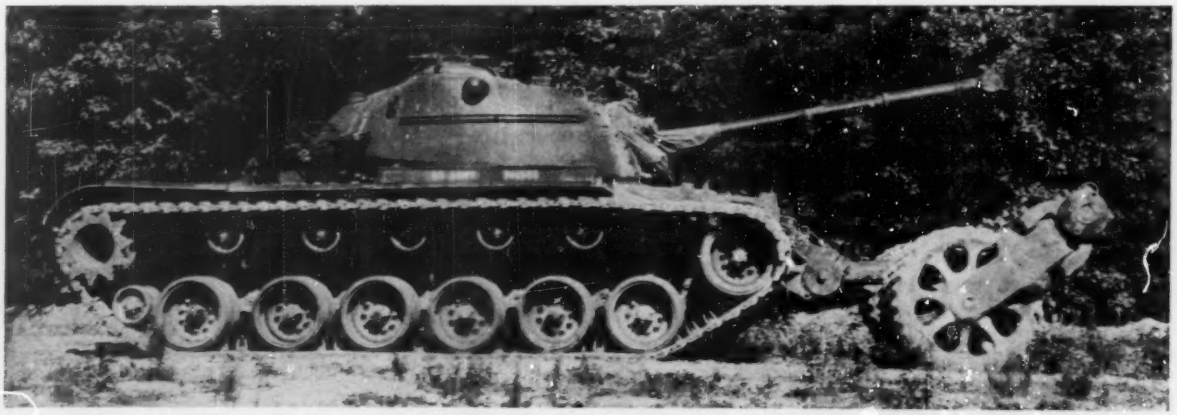
It performs or monitors 16 separate navigation and flight control functions. These include actuating control surfaces to correct pitch and roll, signaling the pilot to increase or decrease speed, checking fuel and target range, providing azimuth and elevation information to the pilot, calculating speed and altitude to intercept its target, and self-checking.

Company officials say that a prototype model was flying as early as 1953. The new computer is not necessarily restricted to interceptor use but could be adapted to supersonic jet transports as well.

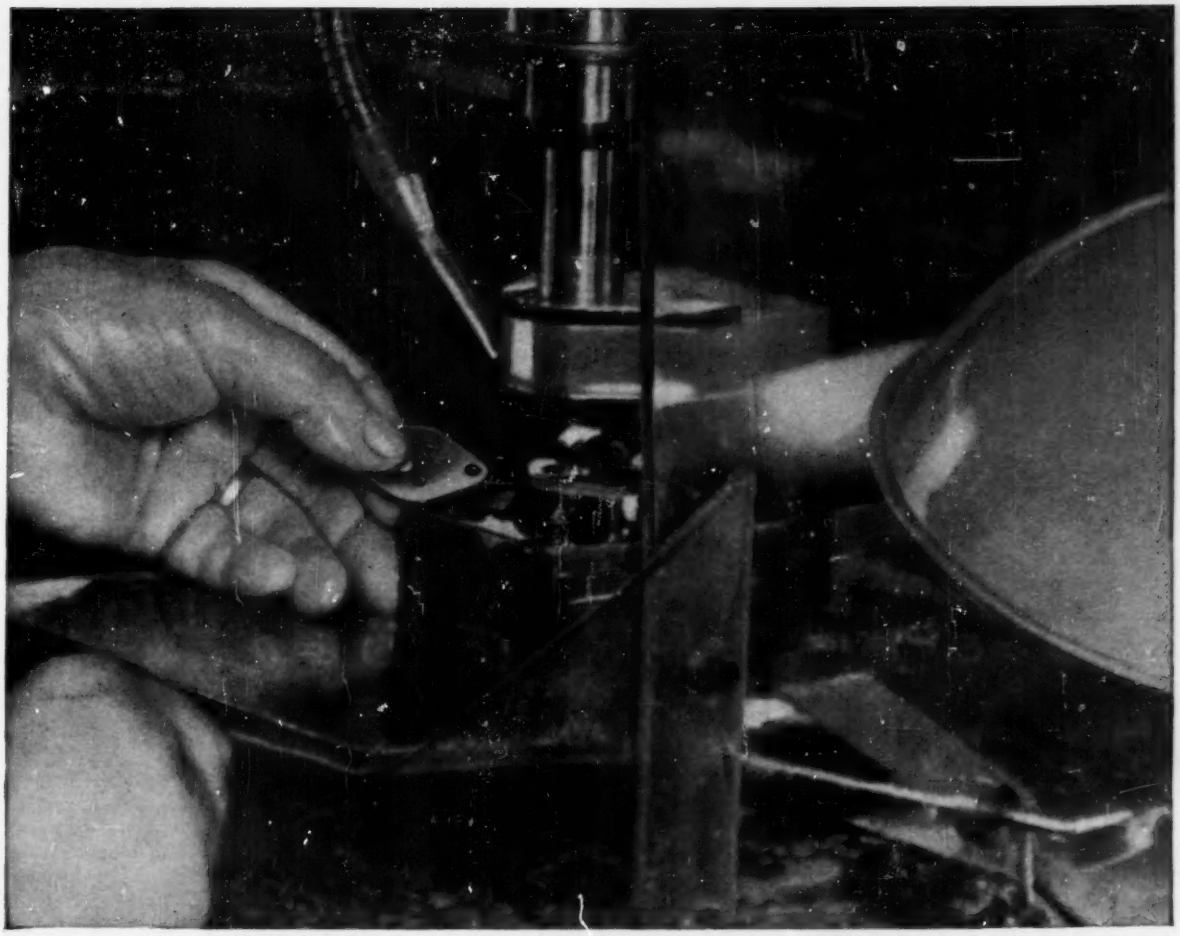
In contrast to most airborne computers, the Hughes unit is of the digital type; weighs only 120 lb. The 4½ cu ft unit contains 4000 diodes. A built-in unit tells if all parts of the control system are functioning properly.



First airborne digital computer in production is inspected by test pilot. Computer is small enough to fit into 21-inch table model TV. It handles all flight and combat problems; leaves pilot free to make tactical decisions. It is shown installed in F-102A interceptor.

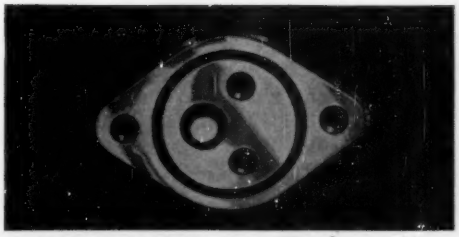


TANK-MOUNTED MINE EXPLODER will eliminate time-consuming search and removal of buried mines, keep fast armored units on the move. Rollers, fabricated of high-strength steel, consist of a series of wheels 4 ft in diameter and 6 in. thick mounted on independent axles. The tank pushes a six-wheel section in front of each track. Outer circumference of roller wheels is designed to eliminate blank spots in ground coverage and wheels are articulated to provide even ground pressure and to absorb shock of exploding mines. In emergency the entire unit can be jettisoned from inside the tank. Roller was designed by Army Engineer R&D Labs.



MACHINING HIGH-PRECISION GROOVE in power transistor bases was easier and faster when Truelove & Maclean, Inc., switched to Anaconda Leaded Copper-126 in strip form.

High machinability plus high electrical conductivity with Anaconda Leaded Copper—now in strip form, too!



TRUELOVE & MACLEAN, INC., Waterbury, Conn., started making bases for power transistors used in Motorola car radios from nonleaded copper. Bases are first stamped then have grooves machined. Specifications are strict; tolerances are close—±.002" on diameter of groove and ±.003" on most other dimensions. Tool cost was high—production slow. They were faced with the necessity of buying additional equipment to meet daily production schedules. An American Brass representative studied the problem, suggested Anaconda Leaded Copper Strip. The results: tool life increased 10 times; production was speeded 25%; over-all costs went down 25%—plus greater accuracy.

When you have to do complicated or precision machining on parts requiring high electrical properties, Anaconda Leaded Copper-126—now available in strip form—can save a lot of trouble and expense.

High machinability. Anaconda Leaded Copper Strip machines almost as readily as Free Cutting Brass. It has a machinability rating of 80%, compared with 20% for nonleaded copper. This means faster production and longer tool life—greater latitude in design.

High conductivity. Anaconda Leaded Copper Strip has an approximate electrical conductivity rating of 99% IACS.

Get in touch with your American Brass Company representative for details of widths and thicknesses available. Or write: The American Brass Company, Waterbury 20, Conn. ATS

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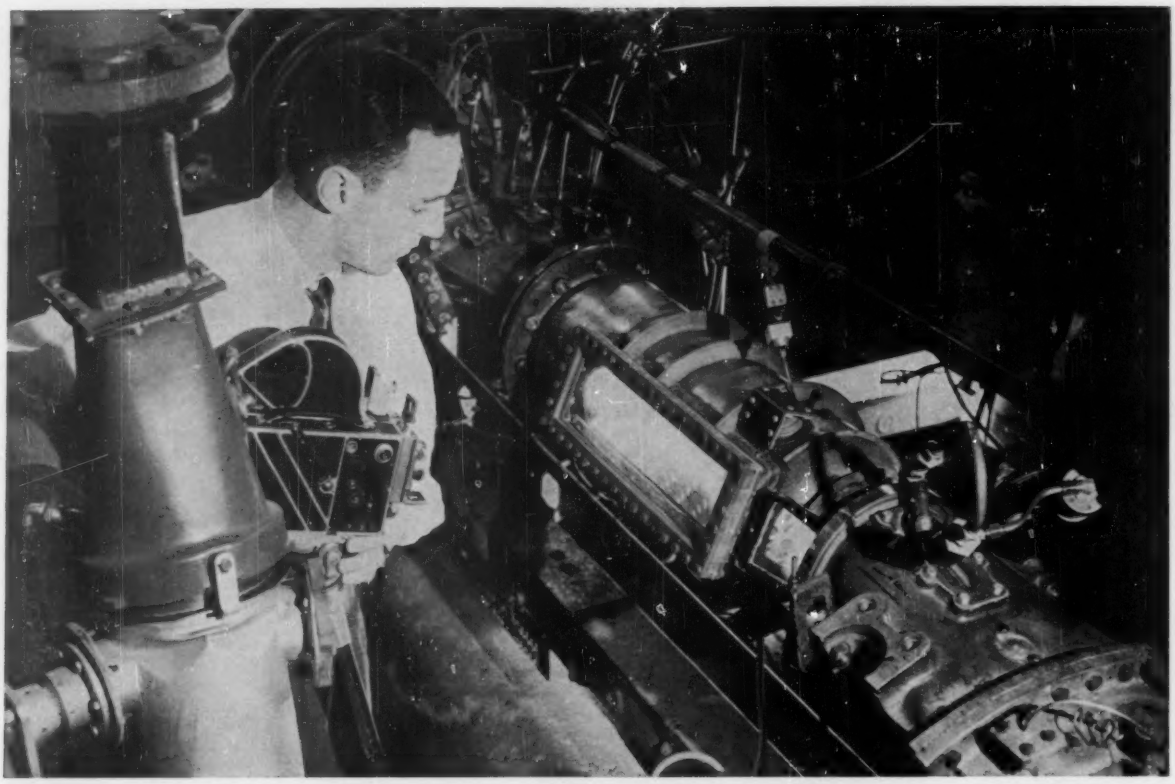


Research to find new fuels with higher energy content has been a major effort of the NACA Lewis Laboratory for more than ten years.

This side of infinity - -

Briefing on TOMORROW'S ROCKET FUELS

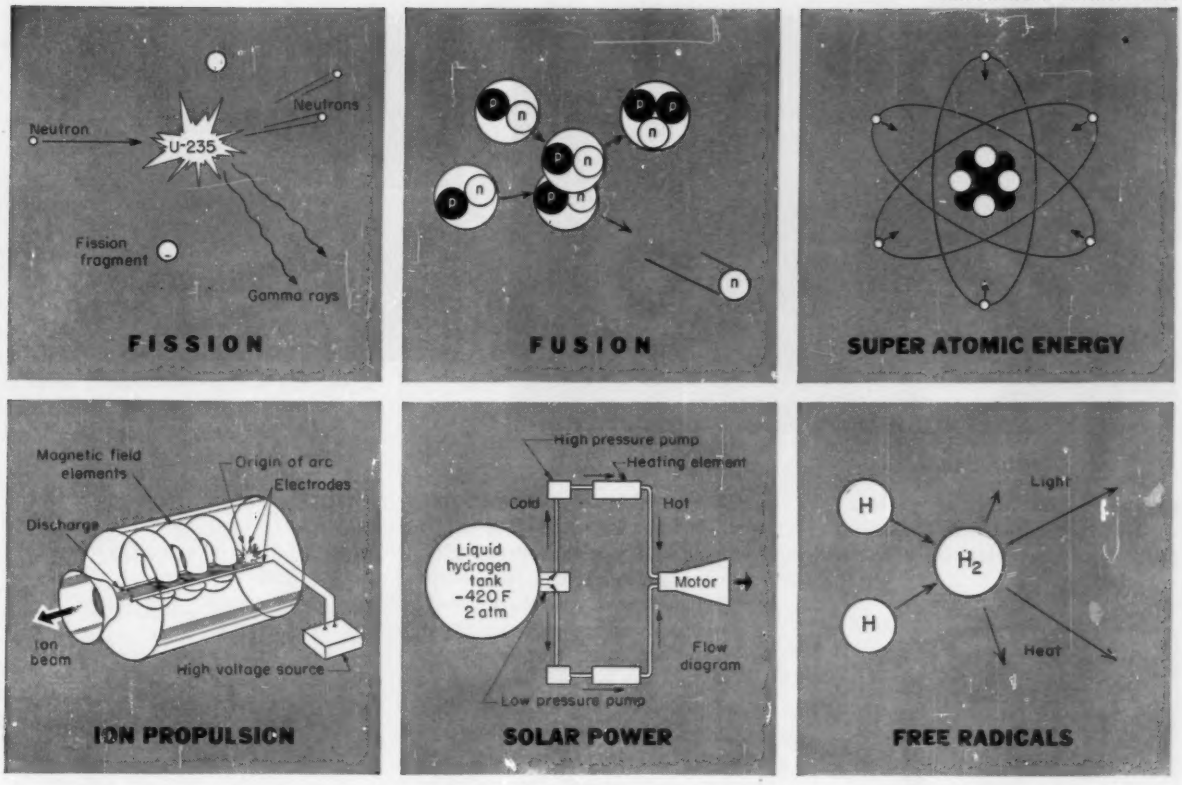
What's the Measure of Rocket Fuel Energy?

In judging a fuel, the first characteristic to be considered is its specific impulse, I_s. I_s (sec) is defined as the ratio of thrust F (lb) produced to the amount of fuel used W (lb/sec). That is, $I_s = F/W$. Theoretical specific impulse may in a chemical system be as low as 150 sec; in a much-talked of free radicals system, as high as 1280.

Specific impulse is a function not only of the propellant, but of the engine design as well. Engine parameters must be specified to compute even the theoretical specific impulse. Its significance to the engineer lies in its direct bearing on rocket performance and payload.

WORLD SPOTLIGHT on rocketry has set in relief all manner of speculation about so-called "super" fuels. Super (used interchangeably with "exotic," "high energy," sometimes "ultra") fuels increase rocket range and payload. Superfuels, substituted for ordinary fuels on basis of equal range, weigh less, give smaller rockets superior speed and performance.

Survey of the superfuels leads inevitably to fields that border on science fiction. Superfuels are an in-between breed, neither quite of today nor tomorrow, so far as reports within the limits of military security tell, but what was thought yesterday to be ten years off may



tomorrow be appreciably closer.

In recent address, Defense Department "czar" of the missiles and rockets program, Assistant Secretary William R. Holaday, said: "Consider the situation we find ourselves in today. Indications are that present available chemical fuels are limited in their ability to produce very high combustion temperatures." His conclusion: new fuels research must provide giant steps in energy gains.

How does one obtain a high energy fuel? Here are some of the possibilities.

FISSION

Nuclear reactor energy, obtained by fission, offers a potential specific impulse improvement over the chemical propellant of at least 50 per cent. Nuclear energy achieves its reaction by ejecting a heated working fluid such as ammonia, helium, or hydrogen. Heat energy released by nuclear fission in a reactor vaporizes the working fluid.

However, heating of working fluids by atomic energy need not be confined to the fission process. Fusion and a "superatomic" process may be speculated on as well.

In the fission process, the nuclei of certain very heavy atoms such as uranium 235 or plutonium 239 are split, by the addition of a neutron, into two smaller fragments of roughly comparable size, plus several neutrons.

FUSION

In the fusion process, the nuclei of two light atoms, such as isotopes of hydrogen, are fused together to produce a single heavier nucleus plus either a proton or a neutron. As in the fission process, the difference in mass between the two fusing nuclei and the single nucleus they produce appears as kinetic energy of the product nucleus; hence, it develops large quantities of heat, which may, it is theorized, be used to heat working fluid for propulsion.

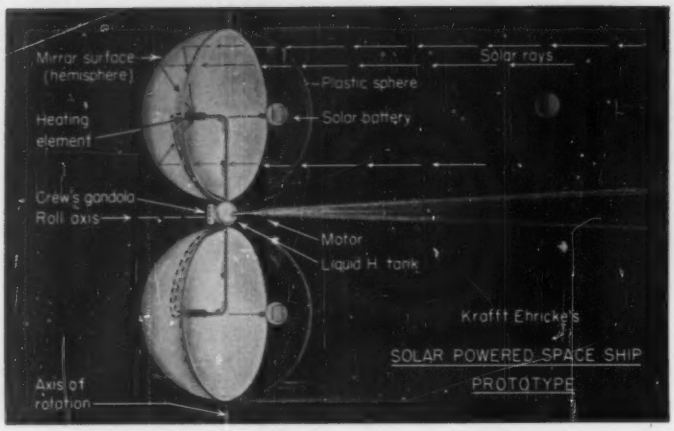
SUPERATOMIC ENERGY

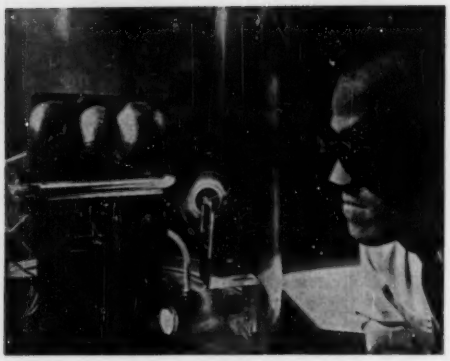
A third possible rocket power use of nuclear energy—superatomic energy—is even more sensational. Navy physicist Dr. Robert L. Carroll has proposed making atoms extremely cold instead of hot. His theory challenges the concept of absolute zero being the coldest possible and the speed of light the fastest possible.

He proposes that as an atom gets colder and becomes less active, its electrons gravitate toward the nucleus and, at the same time, are forced to move faster and faster. If the atom gets cold enough, he suggests, the electrons would plunge into the nucleus and disintegrate it, thus releasing total energy of the nucleus. At last report in November, 1956, the Air Force had agreed to explore the possibility of his theory, and to invite a group of leading scientists to discuss Dr. Carroll's theory at a special conference.

ION PROPULSION

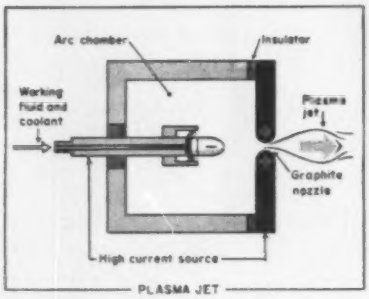
Ion propulsion development, now in study stages at NACA's Lewis Flight Propulsion Laboratory and various industrial laboratories, may lead to application in flight beyond the atmosphere. Ion propulsion develops thrust when an electric or magnetic field is used to accelerate an ion stream. The re-





Accelerated to high velocities in an arc jet, a stream of ions is shown driving small wheel.

sulting reaction may give low-level thrust for gradual acceleration and control of the orbit of a satellite vehicle.



For producing copious streams of ions, possible methods include ionization by arc heating (high temperatures give so-called "plasma jet"), by collision, by electromagnetic radiation, by nuclear reaction, by chemical reaction, by shock tubes, and by surface films in an intense electric field.

SOLAR POWER

Rockets powered by solar energy are a promise of the future. Krafft A. Ehricke of Convair has long proposed a "sunbeam propulsion" system, aimed at eliminating need for energy source when vehicle is in space. Hydrogen working fluid supply, however, would have to be carried from takeoff point.

His proposal: a hydrogen-operated prototype of 16,000 lb gross weight, 11,000 lb of liquid hydrogen, with gondola to carry two crew members. Radiant energy would be scooped up from the sun by two thin-walled plastic spheres, one half of each sprayed with thin metallic film for reflection while the other half would remain highly transparent. Located in the center between the two collectors would be gondola, spherical hydrogen tank and exhaust nozzle. Center portion as well as reflectors could be rotated freely. Hence, the vehicle could accelerate in any direction with respect to the sun. Extremely lightweight construction and accompanying operational limitations are seen as penalties to be paid in design.

FREE RADICALS

As exciting as any is the hope for a propulsion breakthrough by means of free radicals. Although their existence has been known since about 1900, free radicals are still only poorly understood by scientists.

They represent one of the most concentrated forms of chemical energy. The radical, a single atom or larger fragment of a molecule, is highly unstable, remains ordinarily in a free state for only a few thousandths of a second, then recombines chemically, releasing great quantities of energy, largely in the form of heat.

Entirely apart from their proposed use for rocket propulsion, free radicals turn up in various roles in nature, are said to have played an important part in heating and melting the earth billions of years ago. Dr. Bertram Donn, Wayne University physicist, has suggested they may be an important source of energy in space. Dr. Barry Commoner, Washington University biologist, reports free radicals may transport energy in the body, be created by x-rays or ultraviolet light to have an effect in producing cancer and changes in the hereditary cells.

As to their use in rocket propulsion, Mr. Holaday, in an address before a free radicals symposium said, ". . . in the workhorse fuels available today which can be handled logistically, we are limited to specific impulses on the order of 250 to 270 sec. Perhaps by playing with fluorine additives or other things, we can increase this to 400, but not without resultant problems of engine redesign and storage instability. Free radicals may give us specifics starting at 500 sec and going up as high as 1200 with 100 per cent atomic hydrogen.

High interest in free radicals was evidenced by an overflow crowd of 400 scientists from U. S., Canada, and Britain who attended a symposium held at the National Bureau of Standards last September. The symposium, on the formation and stabilization of free radicals, was cosponsored by the Bureau, Johns Hopkins University, the Catholic University of America, and the University of Maryland.

Free radicals as a rocket propellant are under study by the Bureau of Standards and, under contracts with the Air Office of Scientific Research, by Aerojet-General Corp. and Phillips Petroleum Corp. for direct investigation of the propulsion possibility. AFOSR also has contracts for investigations in physics and chemistry to gain basic knowledge about free radicals and their role in nat-

ural phenomena with the University of Minnesota, Laval in Quebec, Canada, Washington University at St. Louis, Rensselaer Polytechnic Institute, Columbia, Washington, Maryland, Stanford, University of California, and Boston University. First AFOSR contract for free radical investigation was issued five years ago.

Nor are these the only interested parties. The National Bureau of Standards program is reported to be receiving Defense Department support and is monitored by the Army's Office of Ordnance Research. Dr. F. O. Rice of Catholic University of America, leader of the group who in 1948 hit upon a technique for trapping free radicals, reportedly is making studies for the Atomic Energy Commission and the Army.

Not until recently have scientists been able to capture and store the molecular fragments for any length of time. One technique employed by Bureau of Standards scientists is to pass a gas such as hydrogen or nitrogen through a 2450-mc radio-frequency field to produce quantities of free radicals in a highly excited state. Before free radicals can recombine, their temperature is lowered to about −450 F. Frozen, they remain in free state for several hours.

In the Free Radicals Section at Bureau of Standards, headed by Dr. Herbert P. Broida, experiments have yielded dramatic results. When product of the breakdown of nitrogen gas begins to freeze on a cold surface, the material emits a bright green glow. As more material is deposited, it gives forth brilliant blue flashes. With flow stopped, a blue-green afterglow persists for several minutes. When the solid is warmed suddenly it emits a flash of blue light.

At 4 deg absolute, free radicals survive for many hours in their free state. Theory is that they are separated from one another by unreactive molecules and atoms arranged in rigid framework. When temperature is raised, the framework yields slightly; radicals wander far enough to combine with each other. Thus, two nitrogen atoms may meet and form the stable nitrogen molecule, emitting just as much energy as required to separate them.

When molecular fragments recombine, much of the energy released is radiated in the form of light, the rest as heat. Color of the light emitted is a measure of the energy required to break apart a given molecule.

As a propulsion source, free radicals pose difficult problems such as storage, handling, and need for heat-resistant materials to withstand tremendous temperatures. Advantage, however, is with the elusive molecular fragments for they promise specific impulses as high as 1280 if, as the ultimate, pure hydrogen could one day be used successfully. B. D. Ross

How Does a Chemical Fuel Work?

Almost all types of rocket motors are heat engines which convert fuel energy into heat and heat into kinetic energy. Propellants react in the combustion chamber to release heat and form gaseous products, which then expand through a nozzle. The gases, exhausted to the rear, impart a forward motion by the reaction principle.

How much heat is produced is the difference between the heat of formation of the propellants and the heat of formation of the reaction products. Also, conversion of heat to kinetic energy becomes more efficient with lighter molecular weight of the fuel products. These three requirements, then, high positive heats of formation for the propellants, high negative heats of formation for their products, and low molecular weight of the products, must be optimized in a good chemical propellant.

What Rocket Fuels Do We Use Now?

The fuel-and-oxidizer combination most commonly used in rocketry today is modified jet fuel and liquid oxygen (for Jupiter, Thor, Atlas, and Titan). Red fuming nitric acid and aircraft kerosene are also in wide use. Boron fuels, developed under the Navy's Project Zip, are slated for limited production in tonnage output plants under construction by both the Callery Chemical Co. and the Olin Mathieson Chemical Corp. Fluorine, hydrogen, other chemicals for propellant combinations are being studied in the laboratory. Among chief problems are storing, handling of extremely low-temperature, unstable elements.

In Vanguard, the first stage burns oxygen and jet fuel, the second nitric acid and aircraft kerosene. In third stage, Vanguard uses a solid fuel. Of the vehicle's total weight, almost 90 per cent is propellant.

Solid fuels are in wide use today in takeoff-assist devices and in missiles such as Honest John and the Nike booster.

But these are, in rocketry circles, considered to be "good old" fuels with modern research stressing newer forms of power: fission, fusion, or "superatomic" applications of nuclear energy; solar heating; ion propulsion; free radicals.

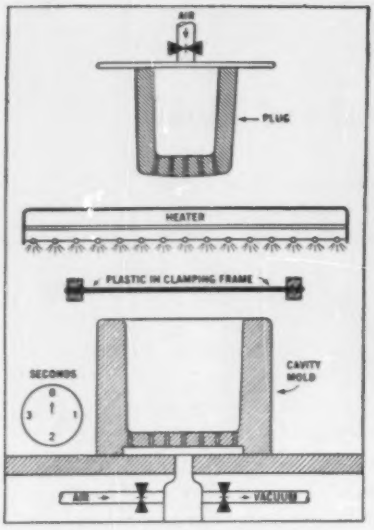
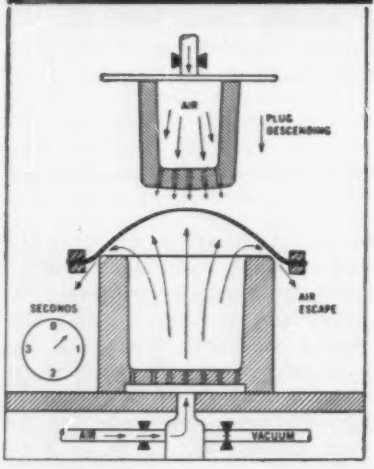


Fig. 1—Plastic sheet, in clamping frame held over cavity mold, is heated to proper molding temperature. Heating varies with plastic type and thickness. Time indicated on dial is 0 at end of heating period.

Fig. 2—(Below) Clamping frame is draped to elevation slightly below top of cavity mold. Air is introduced into cavity mold and pressure build-up causes plastic to stretch into bubble dome. This takes 0.5 second.



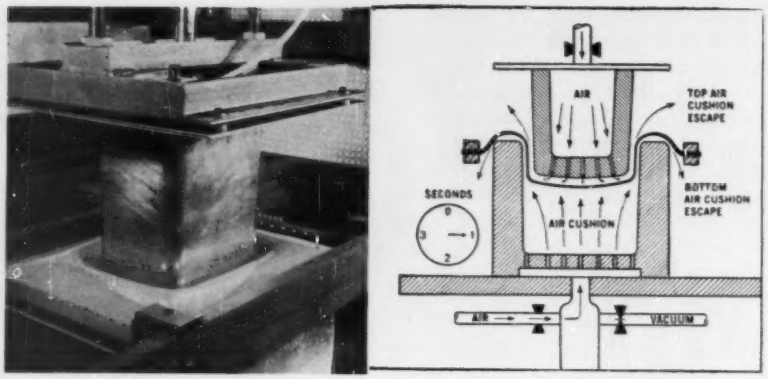


Fig. 3—Hot plug descends into plastic bubble. Air escaping from bleed holes in the plug forms second air cushion. This allows hot plastic to continue to stretch to general shape of final product, yet maintain highly uniform wall thickness. One second has elapsed since end of heating started cycle.

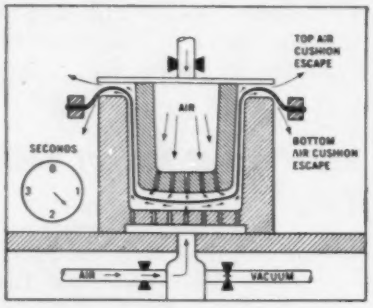


Fig. 4—Hot plug at full descent. Hot plastic is supported between hot plug and cool cavity by cushions of moving air. Continuous introduction of air and allowing air to escape adjusts cushion pressures to prevent pocket build-ups.

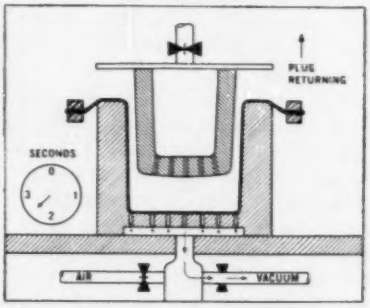


Fig. 5—Vacuum in mold is drawn as air in plug is cut off. Hot plastic snaps to shape of mold. Plug withdraws. Plastic chills and hardens rapidly in cold mold, can be pried loose with assist from air jets. Air also flushes residual heat in mold to prepare for next cycle. Elapsed time is 2.5 seconds.

Air controls hot plastic in new technique for

Deep Draw Vacuum Forming

CUSHIONS OF AIR used in a new vacuum forming process enable deep drawing of thermoplastics on a high production basis. Claims for the process are highly uniform walls and relatively small corner radii in finished products.

The method is said to be equally useful for thin or heavy-gage polyethylene, high-impact styrene, and vinyl. Called "Air Cushion Control," the process was developed by Auto-Vac Co. as part of a design project for Delaware Barrel Co.

One example of a product thus formed is a film development tank shown here. The tank is 12 in. deep and 10½ in. by 8 in. at the top. It has walls that taper only 2 deg from top to bottom. Corner radii are held to ¼ in., and lip radius is ½ in.

Key to the process is the method by which heat-softened plastic is caused to stretch uniformly while seeking to conform to the shape of the mold. This occurs in a brief period during a very fast forming cycle. Jets of air blown from a hot plug and a cold mold act as air cushions. They force the hot plastic to stretch into the general shape of the mold immediately before the cycle's vacuum period.

Primary advantage claimed for the process is the high degree of physical and geometric control of the hot plastic, heretofore nearly uncontrollable. Equally important, the duration of the forming cycle is extremely short. Another advantage is that forming is done against a cold cavity wall to speed hardening.

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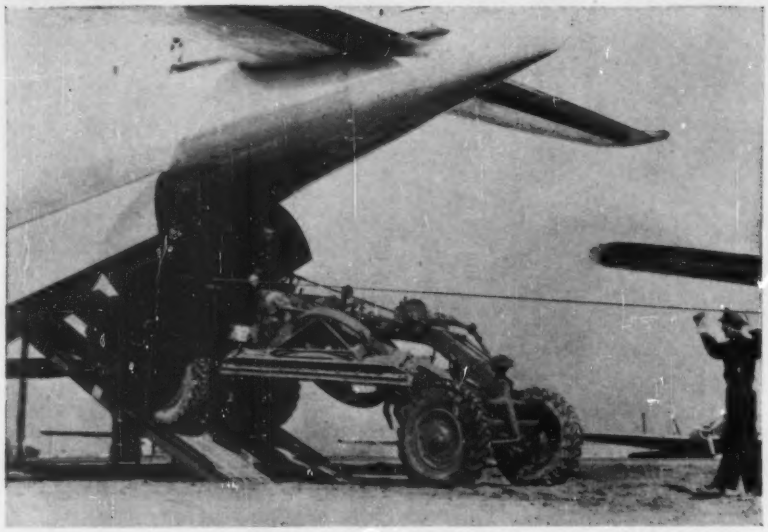


Caterpillar 212 Motor Grader slowly descending load ramp from a C-97 Strato-Freighter. The guy wire is a safety measure to prevent the grader from sliding down the ramp and to control the heavy load better.

Army Makes Construction Items Take-Apartable for Air Transit

Main assemblies of earth movers and road rollers are pinned and bolted to yield pieces that fit and fly in military aircraft

McGUIRE AIR FORCE BASE, N. J.—Common bolts and nuts claimed the limelight recently when the Army Corps of Engineers demonstrated progress-to-date in a program to make its heavy construction equipment air transportable. Simple, rugged, removable fasteners are substituted extensively for welded joints so that earth movers, road rollers, and the like, can be broken into components small enough, and light enough, to be flown to global points-of-use.

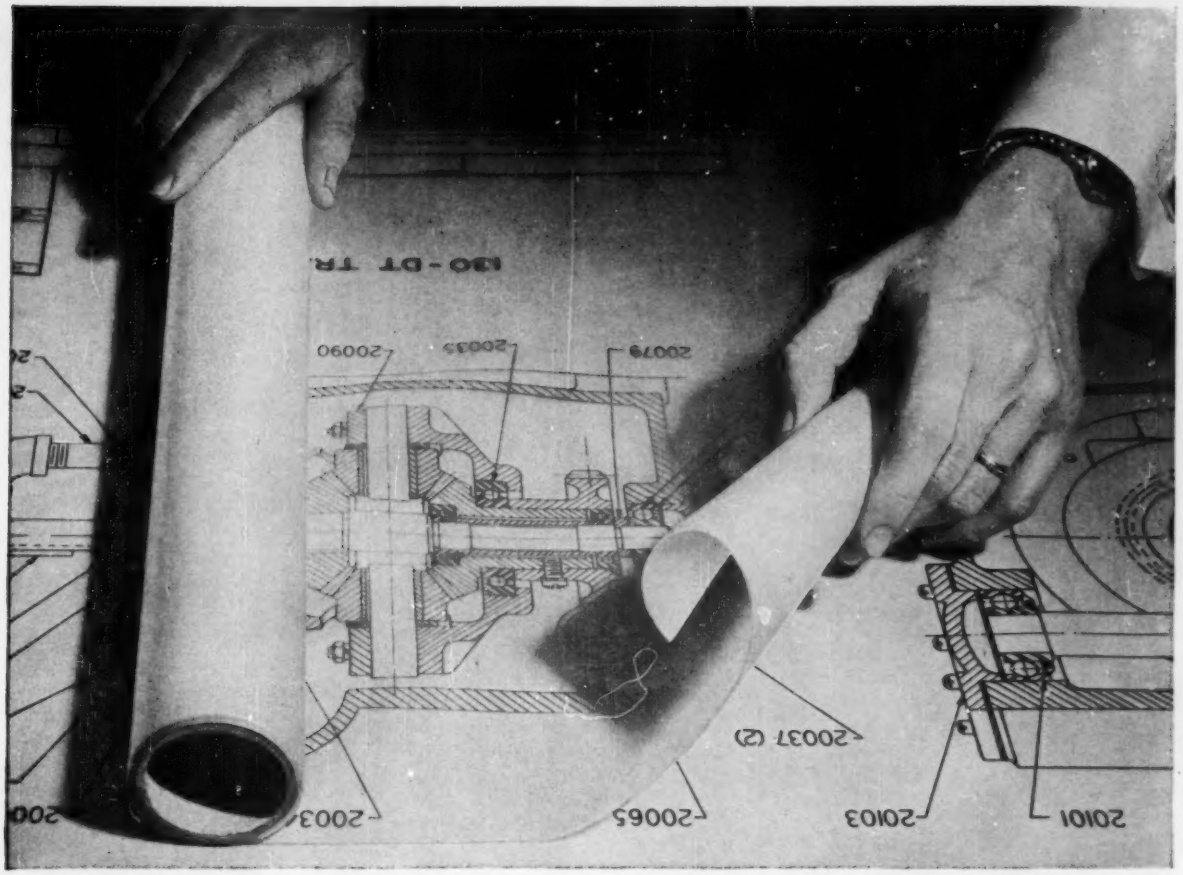
Most of these vehicles are regular commercial models. But in military use, they must keep the pace of fast-moving operations. They must be transportable to points accessible only, or preferably, to aircraft. Disassembly and assembly of equipment and loading and unloading of aircraft must be accomplished quickly, on short notice, by unspecialized personnel, with conventional tools. The Berlin Airlift of 1954 is a case in point. It also spurred the Engineers to initiate the present program. Since then, 80-odd vehicles have been studied by the Engineer Research & Development Laboratories, aided by Albert E. Blomquist and Associates, transportation engineers.

Airplanes used in the studies are: Boeing C-97 Strato-Freighter, Fairchild C-123 Assault Transport, Douglas C-124 Globemaster, and Lockheed C-130 Hercules. Studies have been concentrated on the smallest two or three of these because the others, intended primarily for troop transport, are less likely to be available when needed. Wherever possible, two vehicles of a type comprise one plane load. Nominal loads for each type plane are weights they can manage under trying conditions—on a 100 F day with half the engines out of operation.

One new piece of equipment speeds loading and unloading. This is the Roadable Pad, an oversize aluminum pallet with removable wheels. Loads up to 22,000 lb are tied to the pad itself and form a single handling unit. The unit is hoisted by crane to receive the wheels which enable highway transport at 30 mph. Integral hydraulic systems, hand pumped, on each set of wheels enable the pad to be lowered or raised to the height of plane floors.

In time, the engineers hope these study results will influence original design, but they do not expect manufacturers to sacrifice performance for air transportability. Such components as cabs could be made

Unloading a Tourna-tractor and LPO Scraper from a C-124 Globemaster cargo aircraft. This composite load weighs about 45,000 lb.



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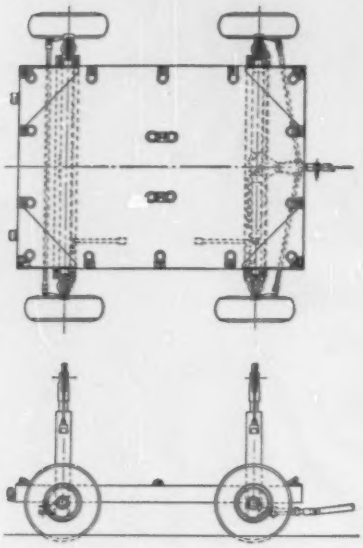

Roadable Pad permits loads of many small items to be handled as a single unit. Wheels are removable. Each wheel has hydraulic elevator which enables leveling and adjusting pad to plane's cargo deck.

of aluminum at low cost and with minimum redesign. It's far more important that items be designed as a few big subassemblies pinned or bolted together, easily assembled and disassembled under field conditions.

Short-Form Radar Gives Weather Data

CAMDEN, N. J.—A compact, weather radar system provides quick local weather conditions at distances up to 150 miles. It consists of antenna, receiver-transmitter, indicator, accessory unit, and a control group.

Developed by the Radio Corp. of America, this new ground weather surveillance radar, according to company officials, "will prove most valuable in predicting and tracking weather disturbances. It will have particular application in airport weather surveillance, television and radio station weather information transmission, construction projects and offshore drilling operations.

Missile Muster

Summaries of guided missiles developed by the three armed services have been announced by the Department of Defense. Principal characteristics and capabilities of these weapons are listed here. Starred items (*) are operational. Missiles had been mustered in MACHINE DESIGN once before—June 27, 1957. The following presentation brings the subject up to date.

Army

Name	Employment
Nike-Ajax*	Surface-to-air
Corporal*	Surface-to-surface
Sergeant	Surface-to-surface
Redstone	Surface-to-surface
Jupiter IRBM	Surface-to-surface
Lacrosse	Surface-to-surface
Dart	Surface-to-surface
Nike-Hercules	Surface-to-air
Hawk	Surface-to-air
Nike-Zeus	Surface-to-air
Talos Defense Unit	Surface-to-air

Nike-Ajax is about 20 ft long, 1 ft in diameter. It has two sets of fins for guidance and steering. It is boosted to supersonic velocity by a solid propellant and its speed is maintained by a liquid-fuel motor. The missile and booster weigh more than 1 ton.

Corporal, equipped with either an atomic or conventional warhead, is capable of engaging targets more than 75 miles from launching site. It follows a ballistic trajectory during most of its flight.

Sergeant is one of Army's newer R&D projects. A ballistic missile, Sergeant will succeed Corporal. It has more power, longer range, higher accuracy.

Redstone is the largest surface-to-surface ballistic guided missile successfully fired in the U.S. It will supplement conventional artillery and can deliver atomic or nonatomic explosives.

Jupiter, derived from Redstone, is the Army's intermediate-range ballistic missile.

Lacrosse is a field artillery missile for close tactical support of ground troops. In any weather, it carries area-type warheads with sufficient accuracy for pin-point targets. It is powered by a liquid-propellant rocket.

Dart is an antitank missile powered by a solid-propellant rocket. It is intended for the use of front-line troops, and it carries a warhead capable of defeating the heaviest known enemy armor. It can be fired from a lightweight launcher and several vehicles.

Nike-Hercules will be the Army's second land-based missile to be placed in the U.S. air defense system. It can travel higher and farther than Nike-Ajax to engage formations of aircraft or single planes. The missile alone is 27 ft long ; the booster, 14.5 ft.

Hawk is the Army's defense weapon against low-flying aircraft. It complements Nike defense against high-level air attack. It uses a solid fuel propellant. Length is about 17 ft; diameter, 14 in.

Nike-Zeus is under development as an antimissile defense against ICBM's that carry nuclear warheads.

Talos Defense Unit is a land-based version of the Navy's Talos Shipboard Missile System. It was turned over to the Army by the Navy at White Sands Proving Ground, Oct. 15, 1957.

Navy

Name	Employment
Sidewinder*	Air-to-air
Petrel*	Air-to-surface
Regulus*	Surface-to-surface
Terrier*	Surface-to-air
Sparrow I*	Air-to-air
Sparrow II	Air-to-air
Sparrow III	Air-to-air
Talos	Surface-to-air
Tartar	Surface-to-air
Polaris IRBM	Surface-to-surface
Bullpup	Air-to-surface

Sidewinder is basically a defensive weapon intended for operation against high-performance aircraft. It is 9 ft long; weighs 155 lb. With a heat-sensitive guidance device, it seeks targets from sea level to 50,000 ft. Its feature is simplicity. It has no more electronic components than an ordinary radio.

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Missile Muster, Cont'd.

Petrel is intended for use against ships at sea. It is carried and launched by patrol aircraft and fleet squadrons. Its length is 24 ft; wingspan, 13 ft; weight, 3800 lb. It is turbo-jet powered.

Regulus, the first operational attack missile to join the Fleet, resembles a swept-wing fighter. It is 30 ft long, travels over 738 mph, has 500-mile range. Regulus is powered by a turbojet engine, guided by an electronic navigator, can carry an atomic warhead. Regulas II has 1000-mile range; speed more than Mach 2.

Terrier is an all-weather missile designed to intercept enemy aircraft at long range and high altitude. It is 15 ft long, weighs about 1.5 tons, has 10-mile range. Terrier is presently installed on two cruisers and one destroyer.

Sparrow I is 12 ft long, weighs 300 lb. A solid-propellant rocket motor gives it 1500 mph speed. It is guided to target by a beam from the launching aircraft's radar. Sparrows II and III are heavier improvements.

Talos is accelerated to supersonic speed by a solid-propellant rocket, then sustained by a 40,000-hp ramjet engine. It is 20 ft long, 30 in. in diameter, weighs 3000 lb. Range is over 25 miles.

Tartar is a solid-propellant weapon, cheaper than Terrier, will go on new guided missile destroyers and larger ships.

Polaris is the Navy's Intermediate Range Ballistic Missile, a counterpart to Jupiter, with special ship-launching provisions.

Bullpup will be used by carrier-based aircraft and shore-based Marine planes. It is 11 ft long, weighs 540 lb. Bullpup is relatively inexpensive, highly accurate, simple in design.

Air Force

Name	Employment
Matador*	Surface-to-surface
Falcon*	Air-to-air
Genie*	Air-to-air
Snark	Surface-to-surface
Rascal	Air-to-surface
Bomarc	Surface-to-air
Thor IRBM	Surface-to-surface
Atlas ICBM	Surface-to-surface
Titan ICBM	Surface-to-surface
Wizard	Surface-to-air

Matador (TM-61) is 39.6 ft long, has 28.7-ft wingspan, is ground-launched, attains 650 mph and 35,000-ft altitude. Powered by Allison jet engine, it has several hundred mile range. Improved Matador TM-61C has greater range, better guidance. Newest Matador TM-76A has integral navigation system.

Falcon, 6 ft long, weighs 100 lb, is powered by solid rocket propellant. It is carried in quantity underwing or in pods; is fired electronically. Model GAR-1 has radar guidance; GAR-2, heat-seeking guidance. In tests, Falcon has knocked down target planes without using explosives.

Genie (MB-1) carries an atomic warhead and was developed for Air Defense Command. It was fired July 19, 1957, from an F-89 Scorpion.

Snark (SM-62) is the first U. S. long-range missile to be test flown and placed in operational use. Over a guided course, it has been flown 5000 miles and accurately placed on target.

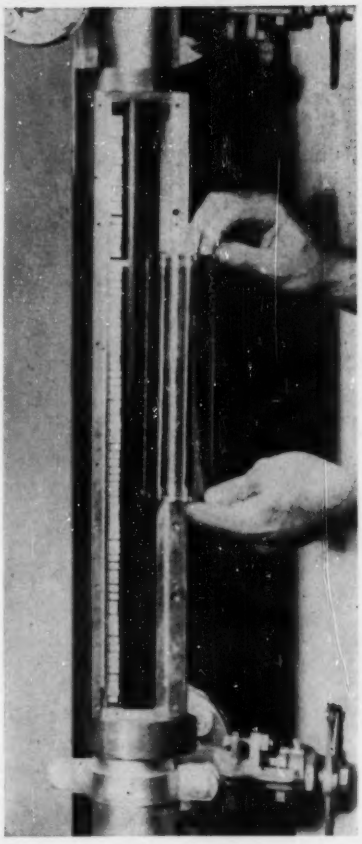
Rascal (GAM-63) is a rocket-powered pilotless bomber to be carried near targets by piloted planes. It is 32 ft long; 4 ft in diameter. The first Rascal has been delivered to Strategic Air Command.

Bomarc (IM-99) is launched vertically, cruises on twin ramjet engines. Length is 47 ft; wingspan, 18 ft; weight, 15,000 lb. In one instance, it attacked from 60,000 ft, 100 miles from launching point, scored a "kill" on a drone target. Bomarc is assigned to the Air Defense Command.

Thor, Intermediate Range Ballistic Missile, has been test fired successfully. It carries its own inertial guidance system and cannot be jammed or deterred from a preset course.

Atlas and **Titan** are Intercontinental Ballistic Missiles under development. Atlas is launched by rocket engines which develop "millions of horsepower within seconds . . . impart speeds well above 10,000 mph."

Wizard is a research and development project in the anti-ballistic missile field.



MAGNETIC WATER-LEVEL GAGE, designed especially for steam plants operating at pressures in excess of 750 psi, is readable under all conditions and will not explode. In place of glass or quartz tube, the instrument uses a nonmagnetic stainless-steel pipe enclosing a metal float which carries a permanent magnet. As the float rides up and down on water it acts magnetically on a row of white painted reeds mounted outside of pipe. Reed closest to top of float is pulled into view through window on front of gage. Reeds can also carry electrical contacts to operate automatic water controls or set off alarms. Designed by Charles Englehard Inc., the new instrument is under test by Navy Bureau of Ships.

Nuclear Power Plant To Be Mobile, Gas-Cooled

FORT BELVOIR, VA.—To gain design data for a mobile, gas-cooled nuclear power plant for military applications, ground was broken recently at Fort Belvoir for the first closed-cycle, gas turbine test facility in the U.S. Information

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If your money comes from making precision equipment, you'll want to know more about the profit-producing powers of Miniature Precision Bearings. These bearings improve instrument sensitivity and reliability — heighten values and often cut costs.

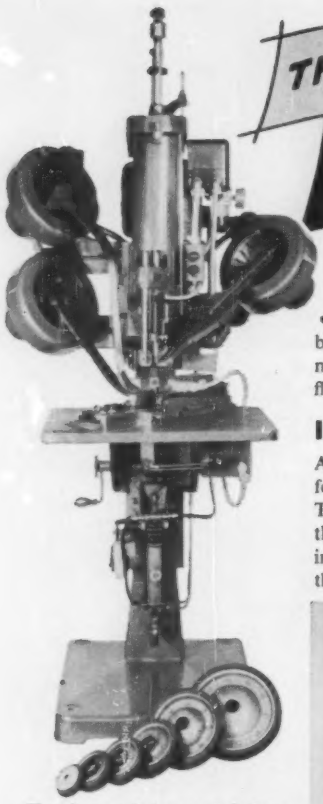
Now possibility and perfection can replace impossibility and imperfection. There are MPB bearings from 1/8" O.D. down — precise within limits one-third the thickness of a postage stamp! Despite its minuteness every ball in an MPB retainer-type bearing rolls in its own coined pocket. Even under extreme temperature changes MPB bearings run smoothly, helping your product deliver continuous precision and top performance.

If miniaturization can help you, so can MPB. Over 500 kinds of bearings — specials if you need them. And we are ready with the world's broadest miniature bearing experience (we own the mint!) to solve your problems and help you mint ideas. Write to Miniature Precision Bearings, Inc., 101 Precision Park, Keene, N. H.

MPB

MINIATURE PRECISION BEARINGS

Circle 417 on Page 19



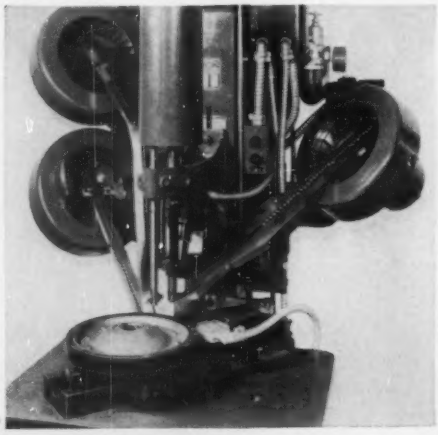
THIS 4 in 1 DPS POWER OPERATION

BOOSTS ASSEMBLY PRODUCTION 300%

• A special assembling machine built on the combination of a Power Screwdriver and three automatic Parts Feeders fastens an inner and outer flange on the rubber tires of

INDUSTRIAL TRUCK WHEELS

A screw, lock washer and nut are automatically fed and oriented, each from a separate parts feeder. The operator simply places the wheel segments in the locating fixture, starts the machine cycle indexing to the proper driving point, at which location the assembly is completed.

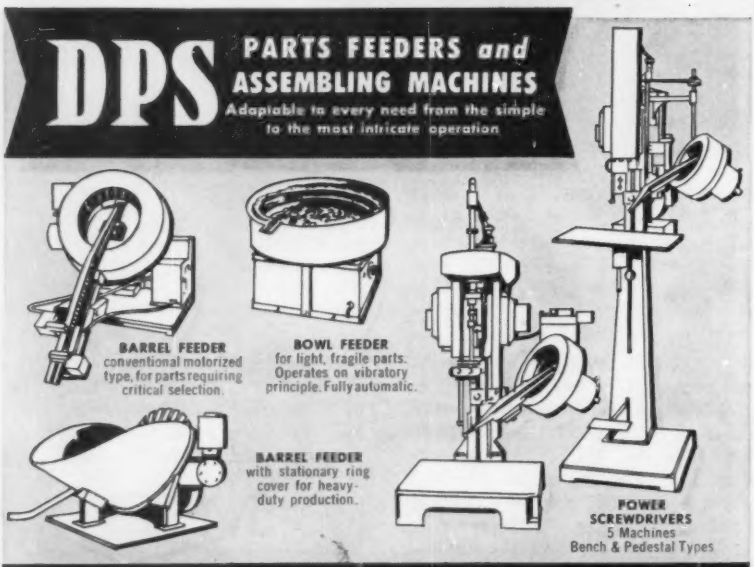


The above unit represents but one of a thousand different applications of DPS assembling machines now in successful operation. Let us show you how you can greatly increase your production at a substantial saving by these modern power methods.

Write for Catalog Send Sample Assembly

DPS PARTS FEEDERS and ASSEMBLING MACHINES

Adaptable to every need from the simple to the most intricate operation



BARREL FEEDER conventional motorized type, for parts requiring critical selection.

BOWL FEEDER for light, fragile parts. Operates on vibratory principle. Fully automatic.

BARREL FEEDER with stationary ring cover for heavy-duty production.

POWER SCREWDRIVERS 5 Machines Bench & Pedestal Types

DETROIT POWER SCREWDRIVER CO.

2801-A W. FORT ST. DETROIT 16, MICH.

gained from operation of this facility will be combined with experience gained from the AEC's Gas Cooled Reactor Experiment. The gas-cooled reactor experiment project is now in the design and component development stage.

The test facility will operate on a regenerating closed cycle with nitrogen as the working fluid. An oil-fired heater will be substituted for the reactor as the heat source in the test facility. The nitrogen is heated to over 1000 F in the heater and expanded through a two-stage axial flow turbine. The turbine drives a two-stage nitrogen compressor and an electrical generator. The power will be dissipated through an immersion heater located outside the building.

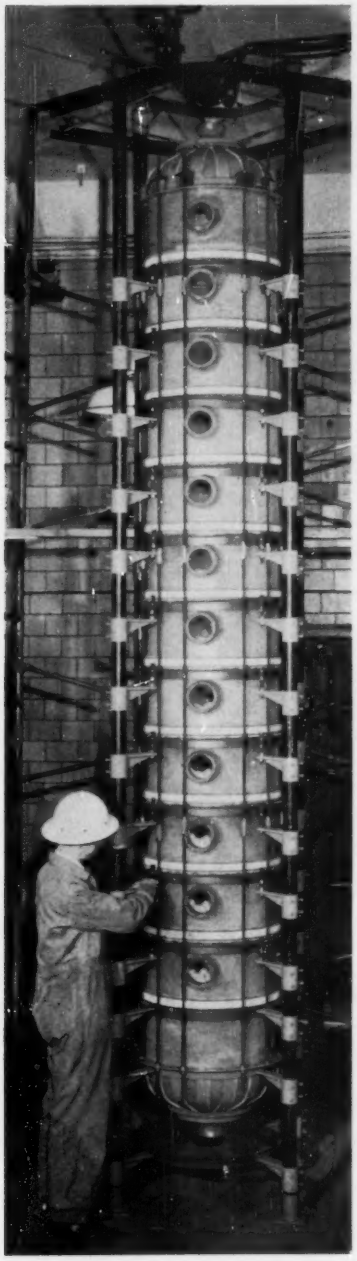
Alarm Systems Cast Eye On Hazards, Babies, Burglars

Miscreants Beware!
Big Brother is Watching

CLEVELAND — Hazards in general, burglars, and babies are going to be competently monitored if three manufacturers of recently announced electrical alarm systems have their way.

One such system, known as the Electronic Sentry, promises to detect hazards and then call up a designated party. According to the Automatic Electric Co., it will respond to the signal from a detecting device such as a thermostat, pressure control, or burglar detector. It will then connect itself across the telephone line, dial a predetermined number electronically, and by means of prerecorded message, inform the person who answers of the nature of the trouble. At the end of a preset time, the unit will disconnect itself momentarily from the telephone line. But if the condition that caused the warning has not been corrected, the system will again dial the number and repeat the warning message until it has.

Another system, this one called the Electro-Sentry and developed by Gulton Industries Inc., is said to offer more than a thousand dif-



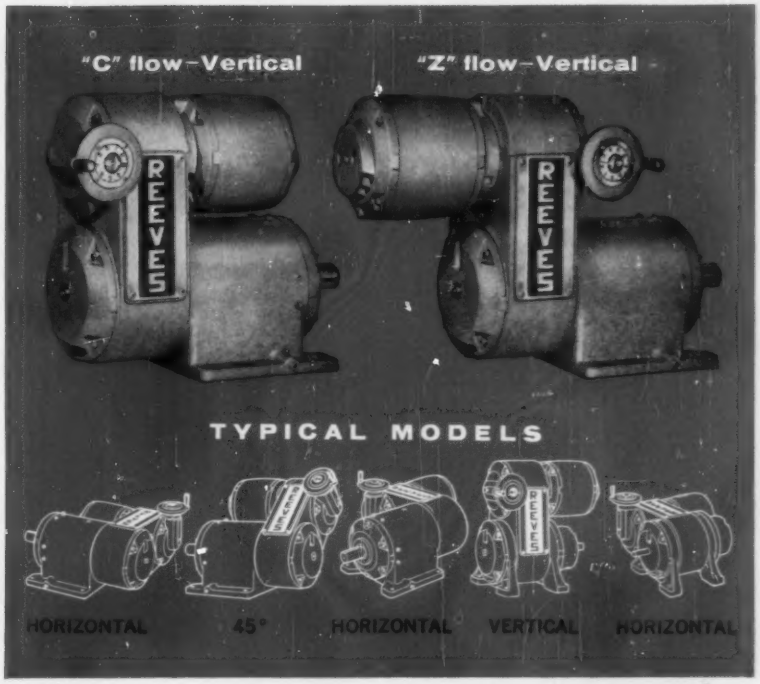
ALL GLASS and believed to be the largest of its kind, a 16-ft distillation column will ensure purity in the manufacture of metallic silicon. Made by Corning Glass Works for a chemical firm, the column is composed of 13 Pyrex sections.

ferent applications in detection, warning, and controlling. In the field of protection, it reportedly senses a three-dimensional pattern so that homes cannot be entered

NEW REEVES®

*Sizes 200-300 Vari-Speed MOTODRIVES**

**200-300 Size, 1 through 5 hp.; full line, ¼ through 40 hp.*



The flexible design of these compact new REEVES variable speed power packages permits hundreds of combinations . . . space-saving, space-fitting *standard* assemblies to meet most installation requirements. All models are available in both "C" flow and "Z" flow styles.

New increased capacity is built in the reducers—single, double or triple stages...new disc assemblies permit wider output speed ranges . . . discs are pre-aligned . . . pre-loaded spring maintains correct belt tension for longer belt wear . . . *exclusive* "close-grooving" lubrication assures free sliding discs . . . new Metermatic system automatically lubricates the motor and variable shaft bearings.

Complete information on all phases of the versatile 200-300 sizes Vari-Speed Motodrives is given in new Catalog. Write for your free copy today—Dept. H32c-M571.

REEVES PULLEY COMPANY

Division of RELIANCE ELECTRIC AND ENGINEERING CO.

Columbus, Indiana

Circle 419 on Page 19

P&B PROGRESS

HIGH SHOCK CRYSTAL-CASE RELAYS

2 NEW RELAYS

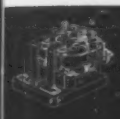
Crystal-Case Size! Permanent Magnet Design.

No Contact Openings. Shock: 100g. Vibration: 30g 55 to 2000 cps.

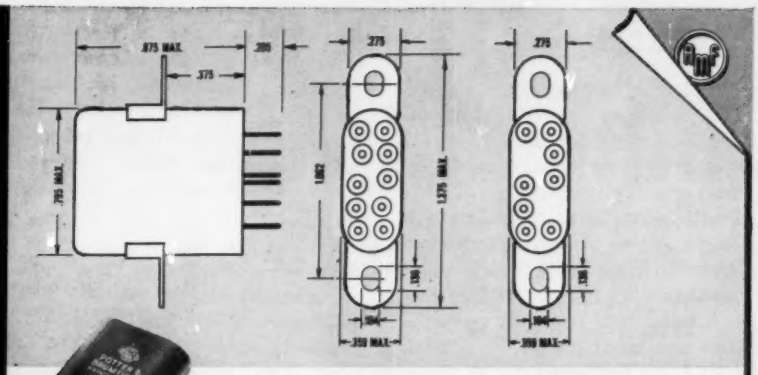
SC NON-LATCHING TYPE—This micro-miniature relay sets new standards—in design, in performance, in reliability. Yet the SC conforms to standard dimensions and circuitry and may be used to replace ordinary crystal-case relays. A permanent magnet in the structure provides *at least twice the contact pressure found in relays of comparable size*. This extra force accounts for the extremely high shock and vibration resistance shown in the specifications.

SL LATCHING TYPE—Unique magnetic latch assures positioning of armature and exceptional pressure. A 1 watt, 3 ms. pulse to either coil transfers contacts. Transfer time is only 0.5 ms. Coils are designed for continuous duty. Has the same exceptional shock and vibration characteristics as the SC.

POTTER & BRUMFIELD, INC., PRINCETON, INDIANA/SUBSIDIARY OF AMERICAN MACHINE & FOUNDRY COMPANY



Over 40 P&B Basic Relays
More than 20,000 Variations



SL—dual coil latching relay. Operates on a 1 watt, 3 ms. pulse at nominal voltage. Permanent magnet latch locks the armature in either position.

SC—non-latching relay with series-connected dual coils. Operates on approximately 1 watt at nominal voltage. Coils must remain energized to hold the armature in the operate position.

SC and SL Series Engineering Data

GENERAL: **Insulation Resistance:** 10,000 megohms, min.
Breakdown Voltage: 1,000 V. RMS.
Shock: 100g.
Vibration: 30g 55 to 2000 cps.; 0.195" max. excursions from 10-55 cps.
Temperature Range: −65° C. to +125° C.
Weight: 17.5 grams (5/8 oz.).
Operate Time: 3 MS. max. with 550 ohm coil @ 24 V. DC. (SL: 630 ohm coil at 24 V. DC).
Transfer Time: 0.5 MS max.
Terminals: (1) Plug-in for microminiature receptacle of printed circuit board.
(2) Hook end solder for one #20 AWG wire.
Enclosure: Hermetically sealed.

CONTACTS: **Arrangement:** 2 Form C.
Material: Gold flashed palladium.
Load: 2 amps @ 28 V. DC, resistive; 1 amp @ 115 V. AC, resistive.
Pressure: SC—13 grams min.; SL—16 grams min.

COIL: **Power:** Approx. 1.0 watt at Nominal Voltage.
Resistance: SL—40 to 1400 ohms; SC—35 to 1250 ohms.
Duty: Continuous.

MOUNTINGS: Bracket, stud and plug-in.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC, ELECTRICAL AND REFRIGERATION DISTRIBUTORS

Potter & Brumfield, inc.

PRINCETON, INDIANA

SUBSIDIARY OF AMERICAN MACHINE & FOUNDRY COMPANY

Manufacturing Divisions also in Franklin, Ky. and Laconia, N.H.

Mail coupon below for further engineering data on P&B's new SC and SL Series relays plus new compact catalog of standard type relays. If you need answers to a specific application problem, write in detail.

Potter & Brumfield, Inc., Princeton, Indiana
Attn: T. B. White, Brig. Gen. USMC (Ret.)
Special Projects Engineer

Please send me complete data on the new SC and SL Series relays, plus the new compact catalog of P&B standard relays.

Name_____

Company_____ Dept. No._____

Address_____

City_____ Zone____ State_____

See our catalog in Sweet's Product Design File

without tripping the alarm.

In the field of retail merchandising, the Electro-Sentry can be used in after-hours promotions by activating outdoor advertising or store front displays, lighting store windows, or starting recorders. Used in this fashion, the unit would start a window display when someone walked or drove past the window, automatically reset itself, and cause a repeat performance for the next passerby.

In protecting small children at outdoor play, the system works in reverse—it signals when there is no activity in a specified area. The alarm will trip when the child strays out of the sensor's range. Indoors, the system baby-sits while the children sleep, signals when they get up. Range of the sensors can be adjusted for a radius of 1 to 25 ft.

A small annunciator, newly announced by the Scam Instrument Corp., is said to be markedly compact. It contains a static switching circuit, which involves no moving parts, thus provides for extremely long life. Although applicable to all processes or systems that require annunciators, the compact unit is claimed to be ideal for smaller systems and machinery.

Seek to Cultivate Scientific Talent

NYU to Sponsor Seminars on Creativity

NEW YORK—A program to recognize and encourage scientific creativity will take the form of a series of seminars with research workers and managers as participants. Another phase of the program will be to establish a specialized reference library to collect and codify literature pertinent to creativity in the sciences.

To be conducted by New York University's Division of General Education, the program according to Dean Paul A. McGhee will concentrate on three potentially fruitful areas. "These are the recognition of talent in young people, the

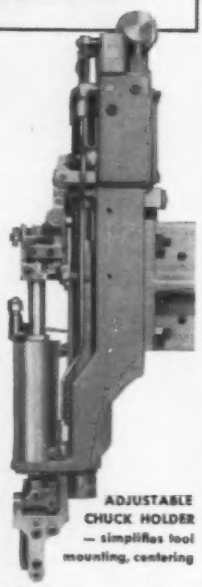
Circle 420 on Page 19

SAVE TIME AUTOMATING SMALL PARTS ASSEMBLY OPERATIONS

SPECIFY

DIXON

"Auto-Positioner"



FITS IN SMALL SPACE—21" X 3¼" X 5" DEEP

ADJUSTABLE CHUCK HOLDER — simplifies tool mounting, centering

- STANDARD HEAD DESIGN—Saves engineering time. Easy to apply to variety of jobs. Operates on ordinary 80# air pressure, 110 volts. Has machined T-slot surface, simple adjustments. Tooling, mounting column, feeders, etc., optional.
- BUILT-IN SENSING—Acts as automatic inspector, assures quality production. Machine stops if part is missing or malformed.
- FAST, VERSATILE—Handles wide range of feedable metal or plastic parts from ⅛" to 3" O.D. at speeds up to 100 cycles per minute. Easy to tool.
- PRECISION-BUILT—Sturdy frame, one-piece super-finished piston and rod, cushioned air cylinder, J.I.C. controls.
- WRITE FOR FULL DATA—New circular gives complete specifications, shows typical applications.

DIXON PARTS ESCAPEMENTS
Releases single parts or in multiples at speeds up to 200 per minute. Standard models available for air, solenoid, or mechanical operation.

DIXON AUTOMATIC TOOL, Inc.
2310–23 rd AVENUE
ROCKFORD, ILLINOIS

Equipment for Automatic Parts Handling and Assembly

Circle 421 on Page 19

utilization of accumulated unused talent in our aging population, and the discovery of the area of greatest creativity in persons with misplaced creative talent."

Participants in the seminars will seek to arrive at ways of dealing with creativity, to delineate creative research patterns, and to foster interscience research projects. Plans are being made to publish the seminar findings.

Meetings

AND EXPOSITIONS

Jan. 27-30—

American Society of Heating and Air Conditioning Engineers Inc. Annual Meeting to be held at the Penn-Sheraton Hotel, Pittsburgh. Additional information is available from society headquarters, 62 Worth St., New York 13, N. Y.

Jan. 27-30—

Plant Maintenance and Engineering Show and Conference to be held at the International Amphitheatre, Chicago. Additional information can be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

"You through with the electric eraser?"

Jan. 28-31—

Institute of the Aeronautical Sciences. 25th Annual Meeting to be held at the Sheraton-Astor Hotel, New York. Further information is available from IAS headquarters, 2 E. 64th St., New York 21, N. Y.

Feb. 2-7—

American Institute of Electrical Engineers. Winter General Meeting to be held at the Hotel Statler, New York. Additional information can be obtained from institute headquarters, 33 W. 39th St., New York 18, N. Y.

Feb. 4-6—

Society of the Plastics Industry Inc. 13th Annual Technical and Management Conference of the Reinforced Plastics Div. to be held at the Edgewater Beach Hotel, Chicago. More information is available from society headquarters, 250 Park Ave., New York 17, N. Y.

Feb. 13-15—

National Society of Professional Engineers. Spring Meeting to be held at Michigan State University, East Lansing, Mich. Further information is available from NSPE headquarters, 2029 K St. N. W., Washington 6, D. C.

March 3-6—

American Society of Mechanical Engineers. Gas Turbine Power Div. conference and exhibit to be held at the Shoreham Hotel, Washington, D. C. Further information is available from Mr. Barry Freer, 1300 Connecticut Ave. N. W., Washington 6, D. C.

March 4-6—

Society of Automotive Engineers Inc. Passenger Car, Body and Materials Meeting to be held at the Sheraton-Cadillac Hotel, Detroit. Additional information can be obtained from SAE headquarters, 485 Lexington Ave., New York 17, N. Y.

March 11-14—

Pressed Metal Institute. Spring Technical Meeting to be held at the Sheraton-Cadillac Hotel, Detroit. Further information is available from PMI headquarters, 3673 Lee Rd., Cleveland 20, Ohio.

Self-aligning

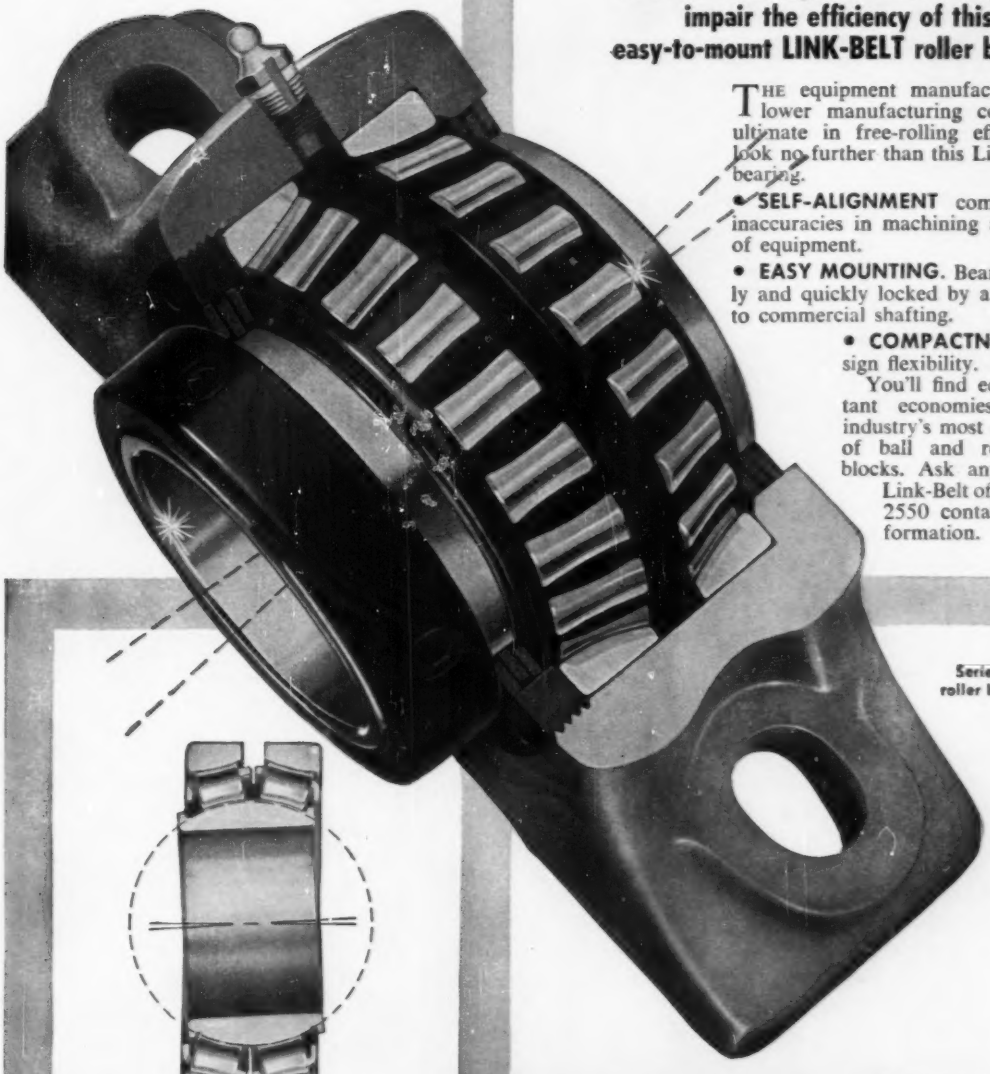
FOR LONGER LIFE

Not even misaligned shafts or supports impair the efficiency of this easy-to-mount LINK-BELT roller bearing

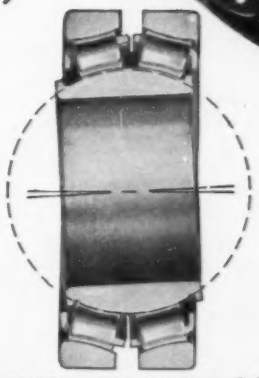
THE equipment manufacturer seeking lower manufacturing costs plus the ultimate in free-rolling efficiency need look no further than this Link-Belt roller bearing.

- **SELF-ALIGNMENT** compensates for inaccuracies in machining and assembly of equipment.
- **EASY MOUNTING.** Bearing is securely and quickly locked by a heavy collar to commercial shafting.
- **COMPACTNESS** offers design flexibility.

You'll find equally important economies throughout industry's most complete line of ball and roller bearing blocks. Ask any one of 40 Link-Belt offices for Book 2550 containing full information.



Series 400 roller bearings



FREE ROLLING—SELF ALIGNING. Spherical inner ring aligns freely in any direction. Load is distributed over entire roller, assuring full capacity. Destructive edge loading cannot occur.

LINK BELT

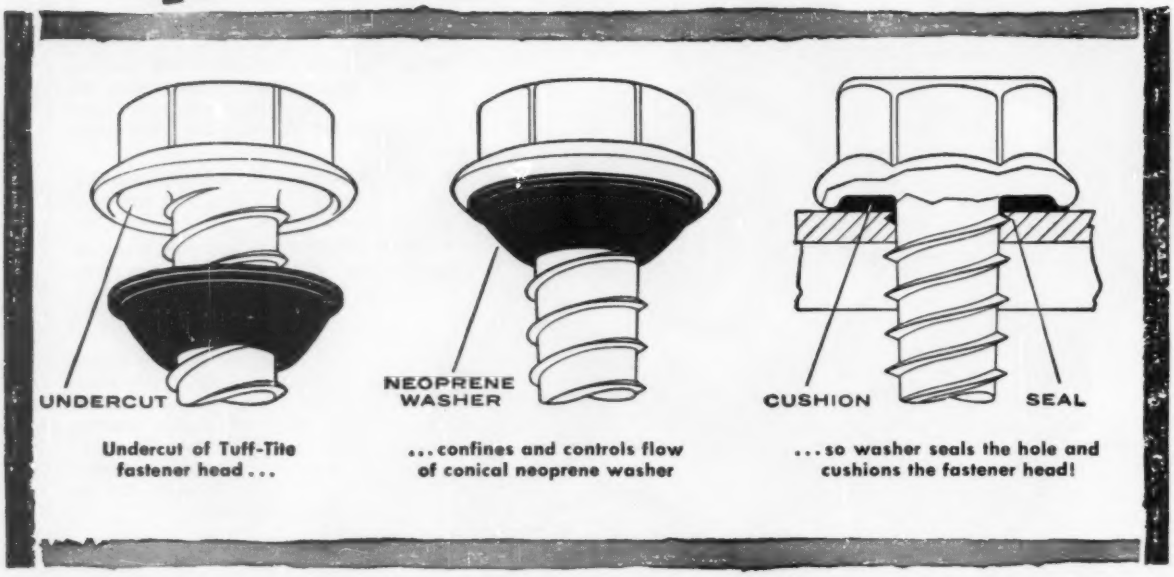
self-aligning ball and roller bearings

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville (Sydney), N.S.W.; South Africa, Springs. Representatives Throughout the World. 14 640-A

Circle 422 on Page 19

For better products

LEAKPROOF...CUSHIONED TUFF-TITE® FASTENERS



Undercut of Tuff-Tite fastener head...

...confines and controls flow of conical neoprene washer

...so washer seals the hole and cushions the fastener head!

Now you can • prevent leaks at fastener holes
• protect fine finishes from fastener damage
• stop vibration noises and squeaks

It's the combination of undercut head design and tough, conically shaped neoprene washer that makes Tuff-Tite fasteners work. The undercut helps confine and control spread of the neoprene washer as it is compressed. The washer's conical shape causes it to flow into top threads and seal the fastener hole.

Tuff-Tite fasteners won't mar fine finishes and they stop vibration noises and squeaks because the neoprene washer spreads itself completely between fastener head and surface. The washer actually cushions the fastener and prevents metal-to-metal contact.

Leakproof, non-marring, shock and squeak absorbing! If you need these fastening advantages, you need National Tuff-Tite fasteners. Write for the Tuff-Tite fastener folder describing this line in detail.

THE NATIONAL SCREW & MFG. COMPANY
CLEVELAND 4, OHIO
Pacific Coast: National Screw & Mfg. Co. of Cal.
3423 South Garfield Ave., Los Angeles 22, Cal.

Tuff-Tite fastener facts

Standard National Tuff-Tite fasteners are available in hexagonal, pan, round and truss head styles for screw diameters No. 6 to ⅜" inclusive... maximum over-all length 1½". Standard fastener types are wood screws, self-tapping screws, thread cutting screws, machine screws and stove bolts. Tuff-Tite fasteners are pre-assembled with neoprene washers.

Washers are molded of neoprene which has a durometer hardness of 85 to 95.

Write for information on *special* Tuff-Tite fasteners.

National PRODUCTS

Fasteners **Hodell Chains** **Chester Hoists**

Use this easy-to-machine steel

TIMKEN® 52100 steel combines hardness, toughness and machinability that's ideal for making intricately shaped parts like slitter knives, aircraft torque wrenches, pump parts, bearing races, collets and machine tool parts.

The fully spheroidized structure of Timken 52100 steel makes machining easy—at no sacrifice in strength or hardenability. It's a high carbon chromium analysis of fine alloy steel with high fatigue and tensile strength, and good hardenability throughout its cross-section.

Timken 52100 steel withstands working pressures up to 200,000 p.s.i. It can be oil-quenched to a hardness of 65/66 Rockwell C. You can depend on uniform quality in every shipment, because we control quality through every production step—from furnace to final inspection.

The Timken Company is the only source of 52100 steel in all three finished forms—bars, tubing and wire. To meet your small run requirements and emergency needs, we stock tubing in 101 sizes—from 1″ to 10½″ O.D. We pioneered the production of 52100 tubing in America and we're the largest domestic producer. Write for a full list of sizes, grades and finishes available. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

TIMKEN *Fine Alloy* **STEEL**

TRADE-MARK REG. U. S. PAT. OFF.

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS STEEL TUBING

Circle 424 on Page 19

Sand... heavy rain... extreme heat...

Nothing stops These Westinghouse Life-Line A Motors

dependably driving oil well pumps in Odessa, Texas district of The Atlantic Refining Company, 24 hours per day, 7 days a week!

"Here's an application," says A. P. Johnston, production engineer at The Atlantic Refining Company, "where we must have continuous motor operation . . . sometimes for as long as 18 months . . . with virtually no maintenance or repair. Many of our pumping stations are remotely located, automatic and unmanned. Any stoppage or motor failure would result in the loss of several hundred barrels of oil. Motor repairs in the field are prohibitive in cost. We must have *complete* motor reliability and that's exactly what we get from our Westinghouse Life-Line® "A" motors."

How about you? Got a really tough motor application which you can't afford to pamper? Then ask your Westinghouse sales engineer to show you how the dependable Life-Line "A" pays for itself through reduced maintenance and repair. Or write to Westinghouse Electric Corp., P.O. Box 868, 3 Gateway Center, Pittsburgh 30, Pennsylvania.

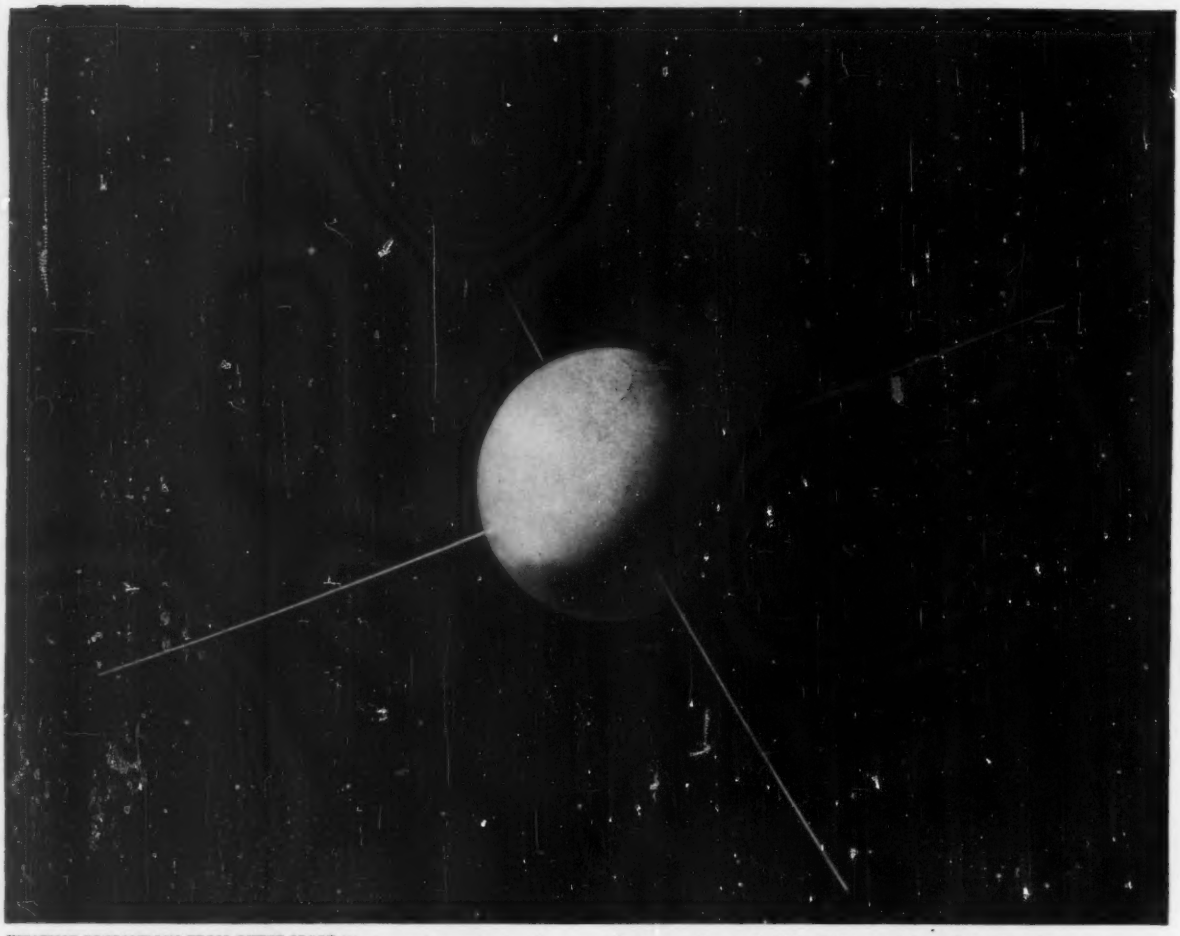
J-22055

YOU CAN BE SURE...IF IT'S Westinghouse

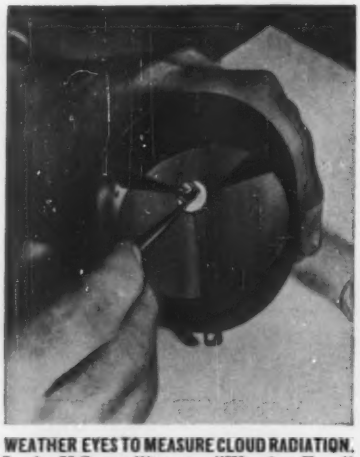
On this pumping unit, the 15-hp Life-Line "A" motor operates in an atmosphere of damaging dust, sand and moisture. Despite continuous, heavy-duty service, motor has never suffered any overheating since first installed. Prelubricated bearings of the Life-Line "A" eliminate periodic greasing . . . keep lubricant in . . . dirt out.

Circle 425 on Page 19

THE NATIONAL SCENE



WEATHER PREDICTIONS FROM OUTER SPACE. Far more accurate weather forecasts will be one of America's scientific achievements during the International Geophysical Year. They will begin when America's earth satellite hurtles into space. Present predictions are based on data covering only 5% of the earth's surface. But forecasters soon will draw clues from cloud patterns, radiation, thickness, types and moisture content—revealed by our satellite orbiting around the earth. National's PHENOLITE will help.



WEATHER EYES TO MEASURE CLOUD RADIATION. In the U.S. satellite, two "Weather Eyes" will peer from outer space at earth's cloud layer. Planned by the U.S. Army Signal Corps Engineering Laboratories and developed by the Perkin-Elmer Corp., Norwalk, Conn. to measure cloud radiation, these 4-ounce instruments are hardly larger than a pack of cigarettes. Each uses an f/0.7 mirror to pick up infrared cloud radiation and focus it on a tiny detector unit.

PHENOLITE WINS BERTH ON EARTH SATELLITE. In the "Weather Eyes" and in the satellite's silicon solar battery system, tiny but essential pieces of National PHENOLITE laminated plastic serve as printed circuit base and insulating spacers. To qualify for this job, PHENOLITE had to meet stringent specifications in dimensional stability, light weight and ability to withstand a wide range of operating temperatures. Perkin-Elmer selected PHENOLITE Grade G-10-865 because it meets all of these requirements.

NATIONAL CAN HELP YOU...

reduce product cost or improve product performance at no added cost. Here's why . . . you can select "the one best material" from over 100 grades of PHENOLITE®, Vulcanized Fibre and National Nylon—without compromise in properties or cost. You can simplify production and purchasing with the timed delivery of 100% usable parts — from a single reliable source. You gain competitively with National's new materials and grades —the direct results of programmed materials research.

You benefit by calling National first. Check Sweets PD File 2 b/na, the telephone directory Yellow Pages, or write Wilmington 99, Delaware, Dept. G-1.

NATIONAL

VULCANIZED FIBRE CO

WILMINGTON 99, DELAWARE

In Canada:

NATIONAL FIBRE COMPANY OF CANADA, LTD., Toronto 3, Ontario

HERE'S ONE — MORE TO COME

New Skinner Valves at Low Prices

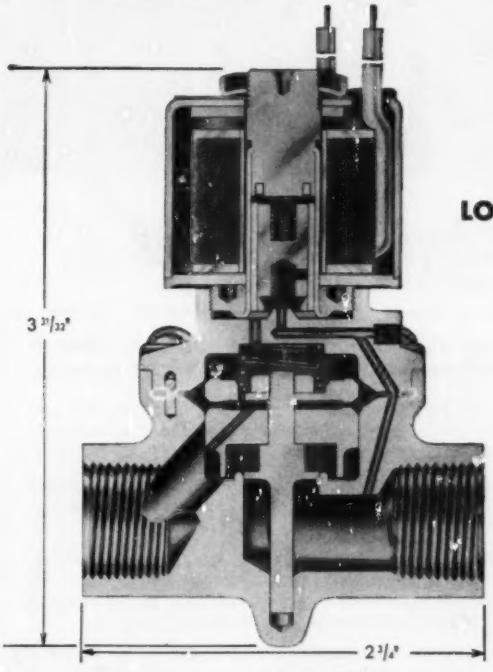
Here it is — one of the many new lines Skinner will bring you in 1958. A new 2-way, normally closed, pilot-operated valve that is lighter in weight — only 1 ¾ pounds — and smaller in size, yet permits full flow through a ½" orifice with ⅜" or ½" pipe taps.

The valve handles pressures from 5 psi to 150 psi, with temperature ranges from —40°F to 180°F, and will operate on all popular AC and DC voltages. It's small but rugged, economical but efficient — manufactured to the highest engineering standards of the Skinner Valve line.

Versatility is also a feature of the new Skinner L Series; modifications are already available for normally open operation, with such options as manual override, explosionproof construction and choice of electrical connections to fit your application requirements.

You can get full details of this exciting, new valve line by writing us direct or by contacting the Skinner Representative or Distributor near you. He's listed in the Yellow Pages. Write Dept. 421.

2-way normally closed shown actual size.



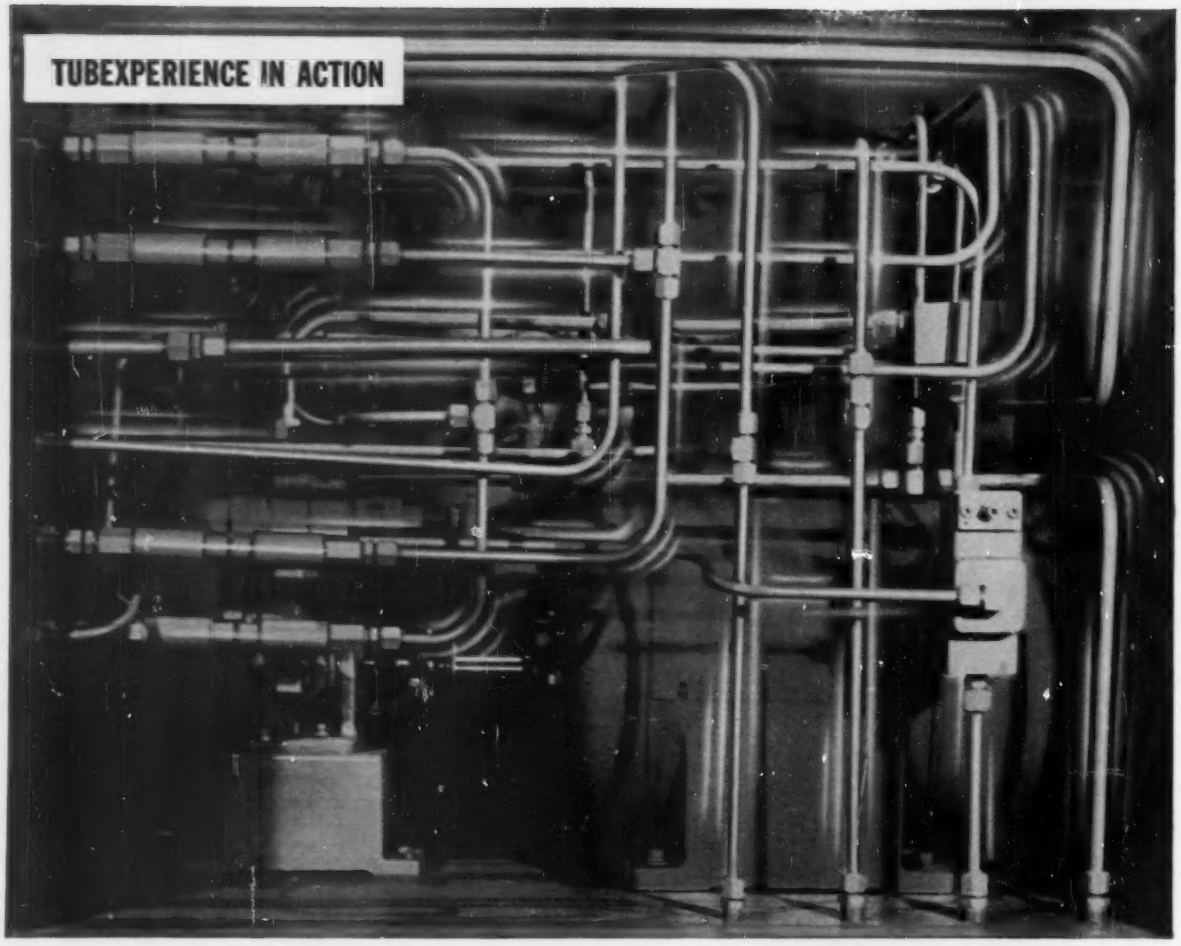
LOOK AT THESE HIGH-QUALITY FEATURES:

- Unique Diaphragm Design — by actual test, this new design outperforms all others — the diaphragm is completely supported at all times. The nylon-reinforced buna diaphragm has a high resistance to media impurities, and only a small area is exposed to pressure, which assures long, trouble-free life.
- So Easy to Mount — so light in weight that it can economically mount directly to line.
- Operates upside down, sideways, in any position — strong spring action snaps valve shut — every time.
- Forged Brass Body — provides low porosity and dense metal structure for rugged application and no leakage.
- Low Wattage Consumption — coil consumes only 8 watts, considerably less than comparable valves.
- Soft, Synthetic Inserts — withstand constant opening and closing of pilot and main orifices — are long-wearing and provide absolute bubbletight operation.
- Internal Stainless Steel Parts — eliminate internal rusting, clogging or contamination.

SKINNER ELECTRIC VALVES
THE CREST OF QUALITY

SKINNER ELECTRIC VALVE DIVISION
NEW BRITAIN CONNECTICUT
105 EDGEWOOD AVENUE

Circle 427 on Page 19



VIBRATION can murder hydraulic lines

Only tubing with high ductility and smooth, uniform surfaces can take this terrific punishment in its stride!

When big motors start delivering power, hydraulic lines go into their vibrating dance. Unless the lines are made from highly ductile material and have exceptionally smooth, uniform surfaces, the ceaseless, pounding vibration may actually cause cracks and ruptures.

Superior hydraulic tubing is available through leading warehouse distributors from coast to coast. Contact the one nearest you today for information—or get a free copy of Bulletin 39 by writing to Superior Tube Company, 2010 Germantown Ave., Norristown, Pa.

HERE'S WHY SUPERIOR (SAE) HYDRAULIC TUBING WILL GIVE YOU LONGER, MORE ECONOMICAL SERVICE

High ductility! *Furnished in dead-soft annealed temper, Superior hydraulic tubing flares easily, bends without pinching, can be readily fabricated for any hydraulic application.*

Non-aging steel! *All Superior hydraulic tubing is made of selected non-aging steel. It keeps its ductility, will not become brittle with age. Carbon content is limited to .12% maximum.*

Bright, smooth, clean! *Special processing gives Superior hydraulic tubing an unusually bright, smooth, clean finish on both OD and ID; reduces turbulence and pressure drop. Shipped with special rust preventive coating on both inside and outside surfaces.*

Fully tested! *And not mere random sample testing! Every length of Superior (SAE) hydraulic tubing is 100% hydrostatically tested at maximum working pressure—giving you realistic performance insurance.*

Superior Tube

The big name in small tubing

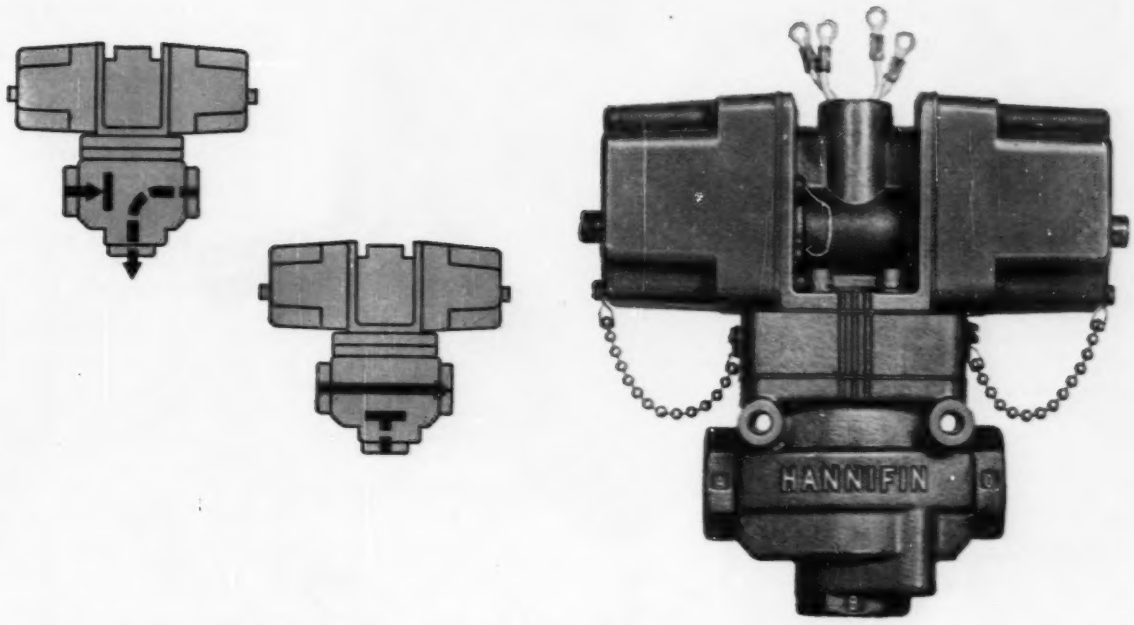
NORRISTOWN, PA.

All analyses .010 in. to ½ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Co., 5710 Smithway St., Los Angeles 22, Calif. • RAymond 3-1331

Setting the pace for automation

...Hannifin valves



Automatic processes call for speed, sensitivity and flexibility in directional air control. Above all, they demand dependability. That is why so many valve users find it pays to choose Hannifin.

Every feature that contributes to dependable performance has been incorporated in Hannifin air control valves. This dependability is the result of never-ending research and development.

In the broad Hannifin line, you will find valves with new exclusive features... valves for practically any kind of automatic sequential operation. All are simple in design, with few and easily replaceable parts.

AIR CONTROL

HANNIFIN

VALVES

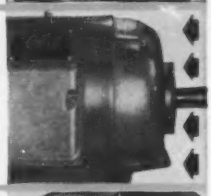
For this complete catalog showing all the Hannifin directional air control valves, write to Hannifin Company, 515 South Wolf Road, Des Plaines, Illinois.

Circle 429 on Page 19

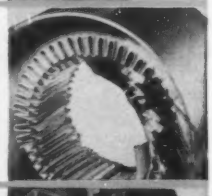
NEW R&M Re-Rated Series 254U All-Weather Motors

"straight through" dual-sweep ventilation eliminates "hot spots"

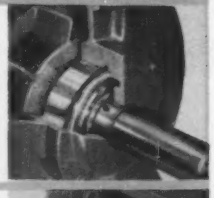
full height end head protection



Mylar insulation increases motor life*



bearings easily inspected by removing cover plate



permanently numbered leads simplify installation and maintenance

*DuPont registered trademark.

Premium Performance

. . . at standard motor prices

R&M Series 254U Motors help pay their own way from the minute you flip the switch! They stoutly resist any hostile environment—moisture, dirt, heat, acid or alkaline fumes—and so live longer. They have push-pull ventilation that won't let dirt settle and keeps motor internally cool—and so perform with full, brisk efficiency. Their oversize bearings are quick and easy to inspect and relubricate—so your maintenance costs dwindle.

This long, trouble-free, vigorous motor life is what R&M means by "Premium Performance"—an extra reward in service and savings every R&M motor offers. These and other big, money-saving advantages shown at left cost no more . . . R&M motors carry standard motor prices!

Write today for R&M Bulletin 520-MD!

Robbins & Myers build motors from 1/200 to 200 horsepower

ROBBINS & MYERS, INC.

SPRINGFIELD, OHIO | BRANTFORD, ONTARIO

News about NEOPRENE

14 years' experience proves NEOPRENE blocks promote clutch-plate efficiency

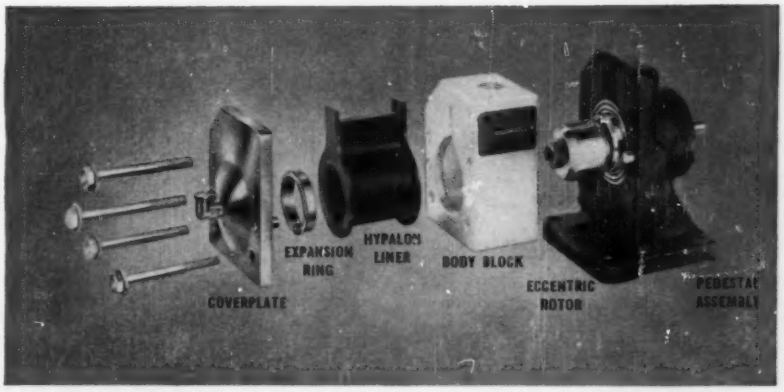
For over fourteen years, taxi and truck fleets have been road-testing a new type of replacement clutch plate—one in which resilient blocks of neoprene have replaced conventional metal springs. Results indicate a vast improvement in over-all clutch performance, and maintenance costs have been reduced nearly 50%.

In operation, the neoprene blocks smoothly transmit the torsional force of the clutch. They retain their elasticity for longer than the life of the clutch facing, despite constant flexing and exposure to heat and oil. And cab drivers report there's less lost motion in the drive line—no clutch "chatter"; no trouble with springs breaking or coming loose. The result is more efficient clutch operation and reduced abuse of clutch facings.

It's an outstanding example of design improvement made possible with neoprene, Du Pont's synthetic rubber. Why not see how you can use Du Pont's neoprene to help solve *your* problems? Just clip the coupon for full information.

Small as they are, these neoprene blocks do a big job as replacements for conventional metal springs. Clutch operation is smoother, quieter, more efficient.

Pump lining of HYPALON® withstands 30% HCl for 9 months without damage



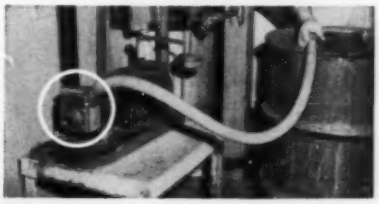
Eccentric revolving inside the liner of HYPALON forces acid through pump from inlet to discharge.

New pump design ended acid leakage; required no maintenance in service

A small rotary pump with a flexible liner of HYPALON synthetic rubber solved a leakage problem for Hoffman-LaRoche, Inc., at its Nutley, N. J., pharmaceutical plant. The pump, used daily to transfer 30% HCl from drums to a measuring tank, is self-priming, leakproof and self-lubricating. It was installed after a succession of other pumps either failed at the packing gland, or couldn't be primed properly. When an equipment change eliminated need for the flexible liner pump, it had operated 9 months with no maintenance whatsoever. Because of this good service, Hoffman-LaRoche engineers plan installation of these pumps at other locations.

Key to the pump's success is its novel design. The tubular liner is flanged and clamped to the exterior of the molded plastic pump housing by end plates. All fluid pumped is trapped between the outside surface of the liner and the pump housing interior, eliminating shaft seals and packing glands. Inside the flexible liner of HYPALON a rotor, eccentrically mounted on the pump shaft, continuously rolls the liquid from inlet to discharge.

The combination of constant flexing and acid attack to which this pump liner was exposed had no effect upon HYPALON. This Du Pont synthetic rubber is made to perform where conditions are severe. For example, HYPALON is completely resistant to ozone, and shows unusual resistance to high (250°-350°F.) temperatures. It is also highly resistant to strong oxidizing agents and weather. For full details on the many properties and design possibilities of HYPALON, just mail coupon below.



Flexible liner of HYPALON prevents leakage . . . eliminate stuffing boxes, shaft seals and check valves.

HYPALON *is a registered trademark of E. I. du Pont de Nemours & Co. (Inc.)*

ELASTOMERS IN ACTION HYPALON® • NEOPRENE

DU PONT
REG. U. S. PAT. OFF.

Better Things for Better Living . . . through Chemistry

☐ I am particularly interested in _____

☐ Send me a free copy of *The Du Pont Elastomers* (a review of properties of neoprene and HYPALON).

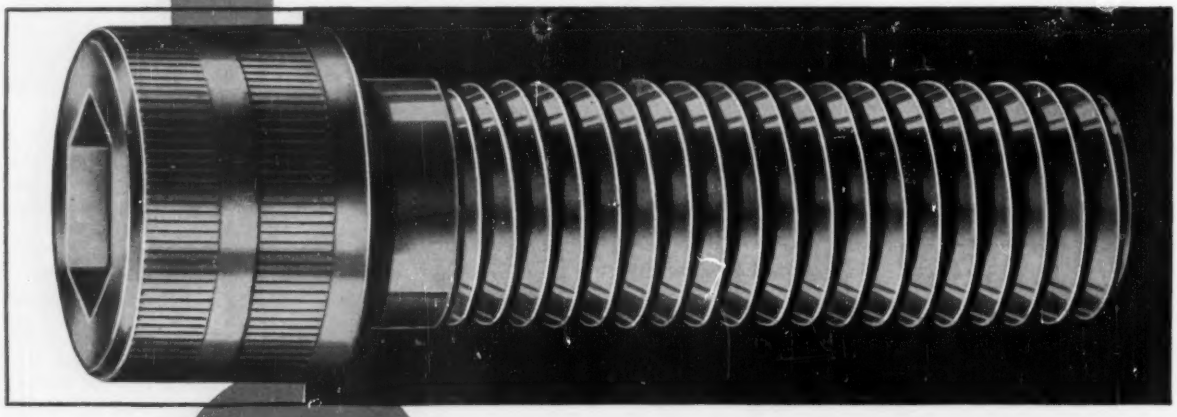
☐ Add my name to the free mailing list of the *Elastomers Notebook* (contains articles based on uses of Du Pont elastomers in industry).

E. I. du Pont de Nemours & Co. (Inc.)
Elastomer Chemicals Dept. MD-1
Wilmington 98, Delaware

Name _____
Firm _____
Address _____
City _____ State _____

Circle 431 on Page 19

Problem: *"Weight is serious problem . . . fewer fasteners the better. If possible, three fasteners should do the work of four. Surface must be flush to give a smooth, streamlined appearance to the product. Only a limited wrenching space is available . . ."*



Solution: *HOLO-KROME SOCKET HEAD CAP SCREWS. Made of special analysis alloy steel heat-treated to 38-42 Rockwell "C" hardness. Sockets are scientifically proportioned for highest strength. Internal hex socket drive assures a smooth, unmarred head. New forging method results in improved fiber flow, tougher screws. Threads are Unified Class 3A fit.*

For the finest in Hex Socket Screws . . . for unmatched Same-Day Service, the name to remember is Holo-Krome.

HOLO-KROME
SOCKET SCREWS
THE HOLO-KROME SCREW CORPORATION • HARTFORD 10, CONN.

SOLD ONLY THROUGH AUTHORIZED HOLO-KROME DISTRIBUTORS

Circle 432 on Page 19

When You Need Reliable Control of Thermal Operations

you need Adlake mercury-to-mercury relays

Match these Adlake abilities against your needs:

- **Perfect function under vibration**
- **Perfect snap-action. No pitting, burning, sticking**
- **No dust, dirt or moisture intrusion—hermetically factory-sealed**
- **Time delay characteristics fixed, unchangeable.**
- **Quiet. Chatterless. Require no maintenance whatever.**

Our engineers will be happy to help you solve your control problem. No obligation. Just write THE ADAMS & WESTLAKE COMPANY, 1173 North Michigan, Elkhart, Indiana. Original and largest manufacturers of plunger-type relays.

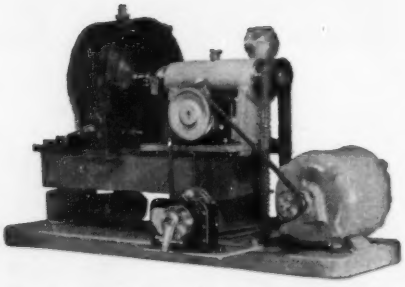
Automatic transmission seal problem—

New National Syntech® proves dependable answer in front pump seal position

Constant temperatures of 250°F, peaks of 300°, continual change in shaft speed, and total inaccessibility of the seal without costly teardown—these are a few of the sealing problems in the front pump of today's automatic transmissions for passenger cars.

To help meet this challenge, National engineers have produced a new oil seal. The new design, a steel encased, spring-loaded unit with Syntech synthetic sealing lip, is characterized by an unusually long flex section in the lip, a special, light-loading tension spring, and the time-tested, low torque Syntech lip itself.

Factory engineers report that the new National seals are proving extremely reliable in the application. Dealers also find the front pump seals are very reliable and do not require early replacement.



To design and thoroughly test the new seal, National engineers developed a new transmission simulator which exactly duplicates front pump operating conditions at all car speeds.

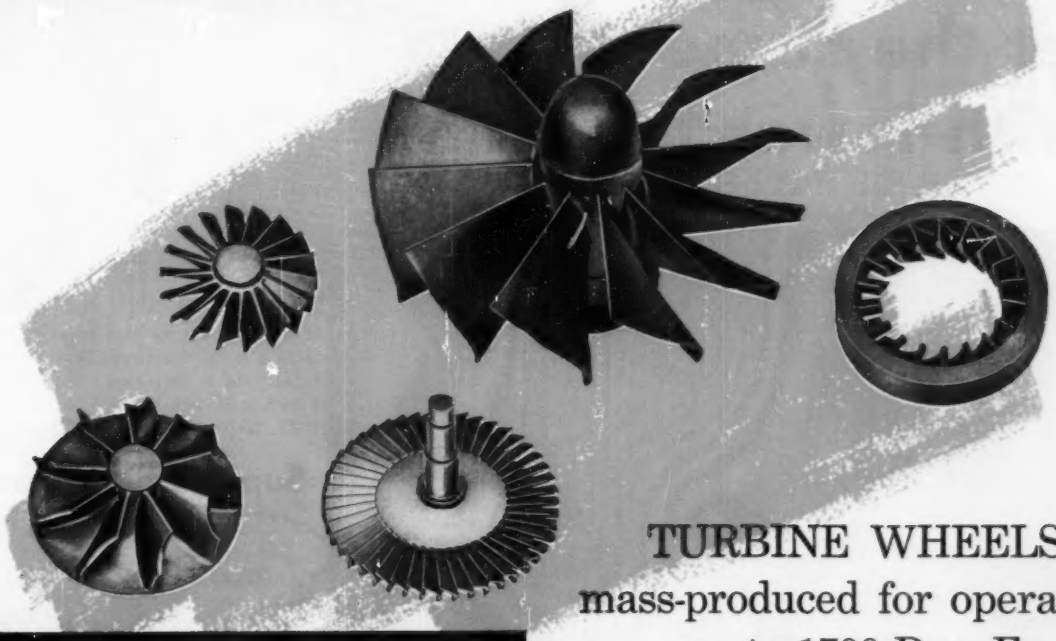
Get real help on seal engineering problems. Call the National Engineer.

NATIONAL SEAL Division, Federal-Mogul-Bower Bearings, Inc.

General Offices: Redwood City, California; Plants: Van Wert, Ohio, Downey and Redwood City, California

Circle 434 on Page 19

HAYNES investment casting solves the *tough* design problems



TURBINE WHEELS mass-produced for operation up to 1700 Deg. F

Special inspection equipment guarantees accuracy. Examinations by Gamma Ray (above) is one of a number of inspection methods used at Haynes Stellite Company's plant to insure top quality control.

Turbine wheels with intricate blading—some as thin as 0.020 in.—and ranging in diameter from 2 to 21 in. are now mass-produced economically by HAYNES' investment-casting method. The blades and wheel are produced as one integral part to close as-cast tolerances.

HAYNES' investment-casting method offers the design engineer a selection of alloys developed for economical operation over a wide temperature range—from room temperature to 1700 deg. F. The cast wheels have high strength and are capable of operating at speeds in excess of 42,000 revolutions per minute.

The freedom to select alloys for performance and to design for top efficiency is one of the big advantages of HAYNES' investment-casting process. For full details, write for the booklet "HAYNES' Investment-Casting." Address Haynes Stellite Company, Division of Union Carbide Corporation, General Offices and Works, Kokomo, Indiana.

HAYNES
ALLOYS

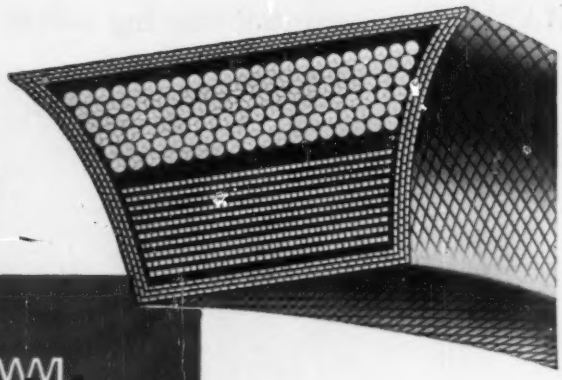
HAYNES STELLITE COMPANY
Division of Union Carbide Corporation

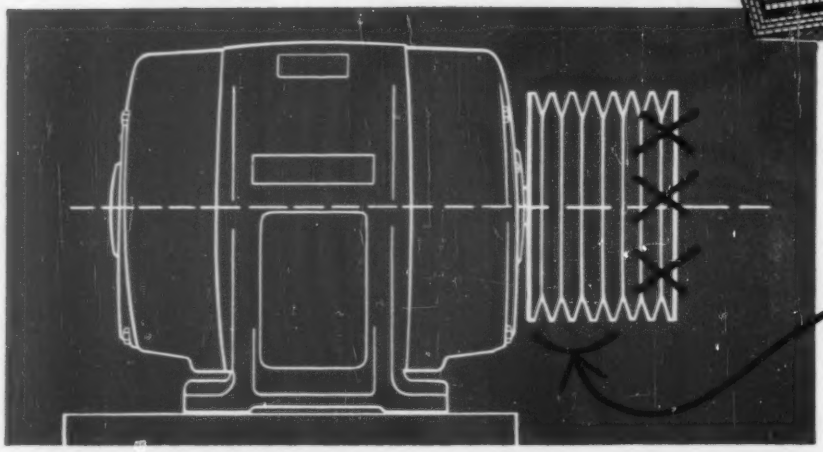
UNION CARBIDE

"Haynes" and "Union Carbide" are registered trade-marks of Union Carbide Corporation

Circle 435 on Page 19

Get the same HP with fewer belts





5 Gates Super Vulco Ropes do the work of 7 standard V-belts

Cut sheave width and weight... save in overall costs of your drive by using Gates *Super* Vulco Ropes with 40% more hp capacity.

5 Gates Super Vulco Ropes will do the work of 7 Standard V-belts. A Super Vulco Rope Drive delivers more HP per dollar invested than any standard V-belt drive.

Sheaves with fewer grooves cost less... weigh less... occupy less space. Your drive design is improved.

Helpful drive data is quickly available to you. Simply call your nearby Gates distributor for advice from a Gates V-belt specialist. Stocks carried in industrial centers throughout the world.

No other V-Belt has ALL these advantages

1. Flex-Weave Cover (U.S. Pat. 2519590)
A Gates exclusive: provides greater flexibility with far less stress on fabric. Cover wears longer... increases belt life... more power available to driven machine.

2. Concave Sidewalls (U.S. Pat. 1813698)
Concave sides (Fig. 1) increase belt life. As belt bends, concave sidewalls become straight, making uniform contact with sheave groove (Fig. 1-A). Uniform contact means less wear on sides of belt... far longer belt life.

3. Tough, resilient Tensile Cords
Super strong resilient tensile cords provide 40% greater horsepower capacity... easily absorb heavy shock loads... reduce number of belts required, save weight and space.

4. High Electrical Conductivity
Built into Gates Super Vulco Ropes for safer drives (in explosive atmosphere).

5. Oil Heat, Weather Resistant
Special rubber compounds make Super Vulco Ropes highly resistant to heat, oil, and prolonged exposure to weather.

The Gates Rubber Company Denver, Colorado

The Mark of *Specialized* Research

TPA 277

Gates Super VULCO ROPE Drives

Circle 436 on Page 19

Circle 437 on Page 19→

DOW CORNING CORPORATION

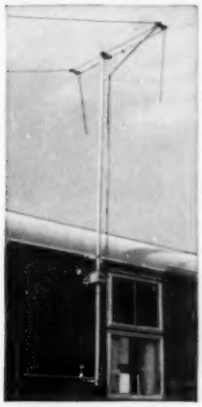
Silicone News

FOR DESIGN ENGINEERS No. 46

LUBRICATE, PROTECT RUBBER WITH SILICONE COMPOUND

More evidence that silicones add to the efficiency and practicability of a design at negligible extra cost is provided by the rotating TV antenna produced by Braund Manufacturing Company, Battle Creek, Michigan.

The Braund TV Selector Tower is a manually-operated, gear-driven antenna especially designed for use with mobile homes. Located outdoors where they are exposed to weathering, the gear box and retaining brackets are sealed with neoprene bushings which require permanent lubrication to assure easy, smooth, quiet operation in any weather.



Braund tested various organic greases in search of a suitable all-weather lubricant. All of them, however, either caked up or washed away within a few weeks. Finally, the problem was solved by switching to semi-inorganic Dow Corning 7 Compound.

An excellent lubricant and preservative for moving rubber parts, Dow Corning 7 Compound effectively lubricates the antenna

(*Cont. Pg. 2*)

SEARS ROEBUCK SPECIFIES SILASTIC FOR DURABLE, HEAT RESISTANT GASKETS

Designers of appliances count on Silastic*, the Dow Corning silicone rubber, to solve even the "hottest" gasketing problems and assure long maintenance-free service. A case in point is the rotisserie door gasket featured on the Kenmore range sold by Sears, Roebuck and Company.

When the Kenmore rotisserie is used as a broiler, its door is left open exposing the gasket to temperatures up to 500 F — heat that would quickly destroy the effectiveness of an organic rubber gasket.

The Silastic gasket, however, stays flexible —will not harden or crack—in spite of repeated exposure to elevated temperatures. The gasket retains its original shape, prevents heat loss and provides a desirable cushioned sound when the door is closed.

Sears specified Silastic for the door gaskets when the rotisserie was designed two years ago. The company has yet to receive its first complaint of unsatisfactory service.

*T.M. REG. U. S. PAT. OFF. *No. 467*

SILICONES PROTECT BEAUTY OF FOIL PLASTIC TRIMS

By making imaginative use of a silicone emulsion, Anchor Plastics Company of Long Island City, New York, has found a practical way to protect the original beauty of "Plastic-Krome" trim.

Polished metal foil imbedded in extruded plastic shapes gives Plastic-Krome trim the sparkle of chromium, gold or copper. Designers like the trim's eye-catching gloss and reflectivity in combination with plastic's economy and serviceability.

For over two years, Anchor Plastics has finished the extrusions with a wipe-on coating of dilute Dow Corning 36 Emulsion. Anchor engineers assert the dry silicone film protects the plastic against marring and scratching, especially important when the trim is shipped in bulk. Moreover, the invisible silicone coating increases the trim's original sparkle.

The hardy silicone film withstands heat and cold, and repels water. Its wetting and spreading characteristics permit easy application of a smooth, continuous, non-oily film. *No. 466*

FOR DATA RELATING TO THESE ARTICLES, CIRCLE REFERENCE NUMBER IN COUPON ON NEXT PAGE

MORE

Silicone News

NEW LITERATURE AND TECHNICAL DATA ON SILICONES

Now Available — 1958 Guide to Dow Corning Silicones gives properties and uses for the silicone products available in commercial quantities. Its 16 illustrated pages suggest numerous ways you can cut costs, simplify designs, improve performance and add new sales appeal to products by making imaginative use of these new engineering materials. *No. 470*

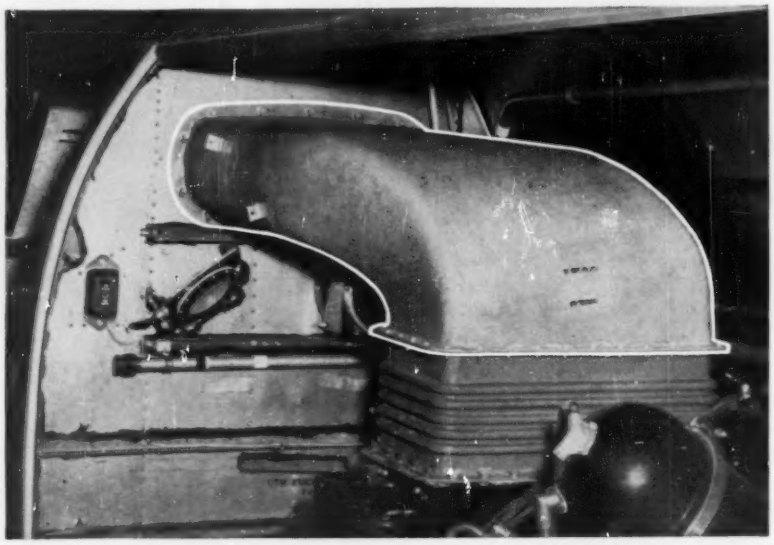
Dow Corning Silicone Lubricants, including oils and greases, are described in an illustrated 8-page brochure that gives their properties, lists their applications, and cites factors which contribute to obtaining longer life. *No. 471*

Protective Finishes and Maintenance Paints, made with Dow Corning Silicones, are available from more than 50 formulators listed in a 4-page brochure that describes how these heat, moisture, and oxidation resistant coatings improve product finishing, and reduce maintenance costs. *No. 472*

New Silicone Coating for paper and paperboard keeps gummy and tacky materials from sticking to all types of bags, boxes, inner liners, wraps and interleaving sheets. Will not migrate; will not contaminate materials that come in contact with it. New brochure containing sample papers describes how Silicone Coating aids packagers and processors of sticky products. *No. 473*

Silicones as Dielectrics. Just published. A 12-page, fact-filled must for design engineers. It's a convenient selection guide to the silicone dielectrics most adaptable to particular applications that range from electronic components and assemblies to power distribution equipment and motors. *No. 474*

Silastic RTV vulcanizes at room temperature. It provides a means of using silicone rubber in those applications where a heat cure is impractical or cannot be tolerated. Available in different consistency grades, Silastic RTV retains good physical and dielectric properties. *No. 475*



MAKE BETTER HOT AIR DUCTS WITH SILICONE-GLASS LAMINATES

Silicone-glass structural laminates are now becoming almost common place, especially on aircraft. Lighter, and easier to fabricate than stainless steel, silicone-glass laminates retain a higher strength-to-weight ratio at elevated temperatures than many light metals.

Douglas Aircraft's Long Beach Division, for example, has made excellent use of these new heat-resistant structural materials for hot air ducting on their C-133A. Among other advantages, Douglas cites the following reasons for switching to silicone-glass laminated structures—

1. Outstanding heat resistance. Silicone-glass laminates are the only plastic structures that can withstand their flame test — 15 minutes at 2000 F— without flame penetration.
2. Low cost fabrication. Forming silicone-glass structures on plaster break-away molds is much cheaper than drawing stainless steel, especially with complex configurations.
3. Weight savings. While specific application data are confidential, silicone laminates are considerably lighter than stainless steel.
4. Glass fibers bonded with Dow Corning silicone resins retain greater strength-to-weight ratio at high temperatures than metals. *No. 469*

RUBBER PRESERVATIVE *(Continued)*

mechanism over a broad temperature span, more than meets all weather requirements and lasts indefinitely. Thousands of silicone lubricated Braund units are in use all over the North American continent without a single complaint to date. Furthermore, the company now plans to use the silicone compound on larger antenna units for conventional homes.

What about cost? "The expense of Dow Corning 7 Compound per unit is so small, we don't even include it in our cost breakdown," writes C. L. Braund, "but we couldn't operate our mechanism without it." *No. 468*

Dow Corning Corporation, Dept. 681, Midland, Michigan

Please send me: 466 467 468 469 470 471 472 473 474 475

NAME _____

TITLE _____

COMPANY _____

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SILICONE NEWS is published for product design and development engineers by

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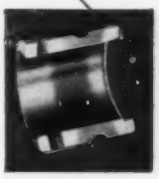
SEALMASTER'S EXCLUSIVE COMBINATION OF FEATURES ARE SETTING THE PACE!

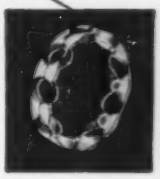
When you design, you design your products for maximum performance—and **Sealmaster** helps you attain it. **Sealmaster** Ball Bearing Units are engineered and manufactured with the same painstaking quality control you would insist on maintaining within your own plant. **Sealmaster's** exclusive combination of features assure you of maximum performance for each bearing. You'll want full information on how important these features are to you and your own product's performance.

LOCKING PIN & PERIMETER DIMPLE—prevents rotation of outer race and assures positive lubrication.

LABYRINTH-SEAL—keeps dust and dirt out and lubricant sealed in for long bearing life.



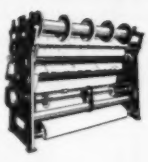
ZONE HARDENING—assures positive race to shaft holding power.



LANDRIDDEN BALL RETAINER—eliminates ball wear, traps grease and prevents churning.

...For Outstanding Bearing Performance

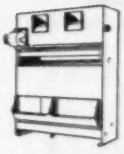
MACHINE TOOLS
SEALMASTER quality pays off where the trend is to continuous, fast, automatic equipment.



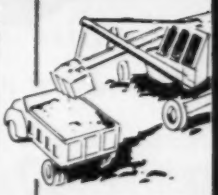
TEXTILE INDUSTRY
Clean, fast production is assured with SEALMASTER Bearings.

FARM MACHINERY
SEALMASTER Ball Bearing Units keep dust and dirt out, lubricant in...a feature Farm Machinery demands.

CONVEYORS
SEALMASTER Ball Bearing Units are featured by manufacturers of many types of conveyors.

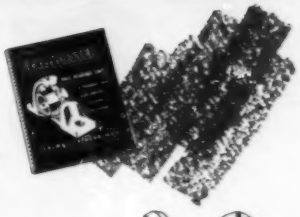


AIR CONDITIONING
Quiet, trouble-free performance is assured with SEALMASTER. Find out about new rubber mounted units.



CONSTRUCTION MACHINERY
SEALMASTER Ball Bearing Units provide the features for gruelling performance in construction and materials handling equipment.

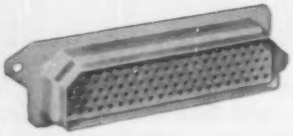
SEALMASTER® BALL BEARING UNITS



Write for Bulletin 454

SEALMASTER BEARINGS A DIVISION OF STEPHENS-ADAMSON MFG. CO. 18 RIDGEWAY AVENUE, AURORA, ILL

What's *new* for you in CANNON PLUGS



DPJ-33S

DPG-34P

- Vibration
- Moisture
- Pressure

▶ **PROTECTION**

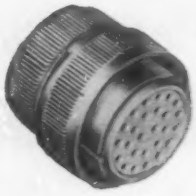
with new DPJ and DPG Connectors

New DPJ and DPG Connectors feature sealing by means of a rubber seal around the insert faces. Exceptionally good protection against vibration and undesirable pressure and moisture conditions is provided. The DPG currently is available in 5 different insert arrangements, the DPJ with 3 insert layouts. **Write for Bulletin DP-101 TODAY!**

new

"EX" SEALED CONNECTORS

- **No Potting Required**
- **Light weight**



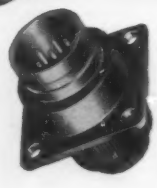
New EX Connectors feature a monobloc silicone insert into which the contacts are inserted after wiring. When the endbell is tightened over the insert, the contacts are completely sealed . . . giving a sealed connector of minimum weight without potting.

EX plug assemblies are currently available in four shell configurations with socket contact inserts . . . EX05, EX06, EXG06 and EX08. They are basically identical with the exception of endbell variations in each case. EX plugs mate and seal with standard AN, AN-E, and GS type receptacles, and are available in practically all AN layouts using #12 or #16 contacts from sizes 8S to 28. **Write for Bulletin PR-EX TODAY!**

new

"Q" MINIATURE CONNECTORS

- **Self-Locking**
- **Sealed**
- **Vibration Resistant**



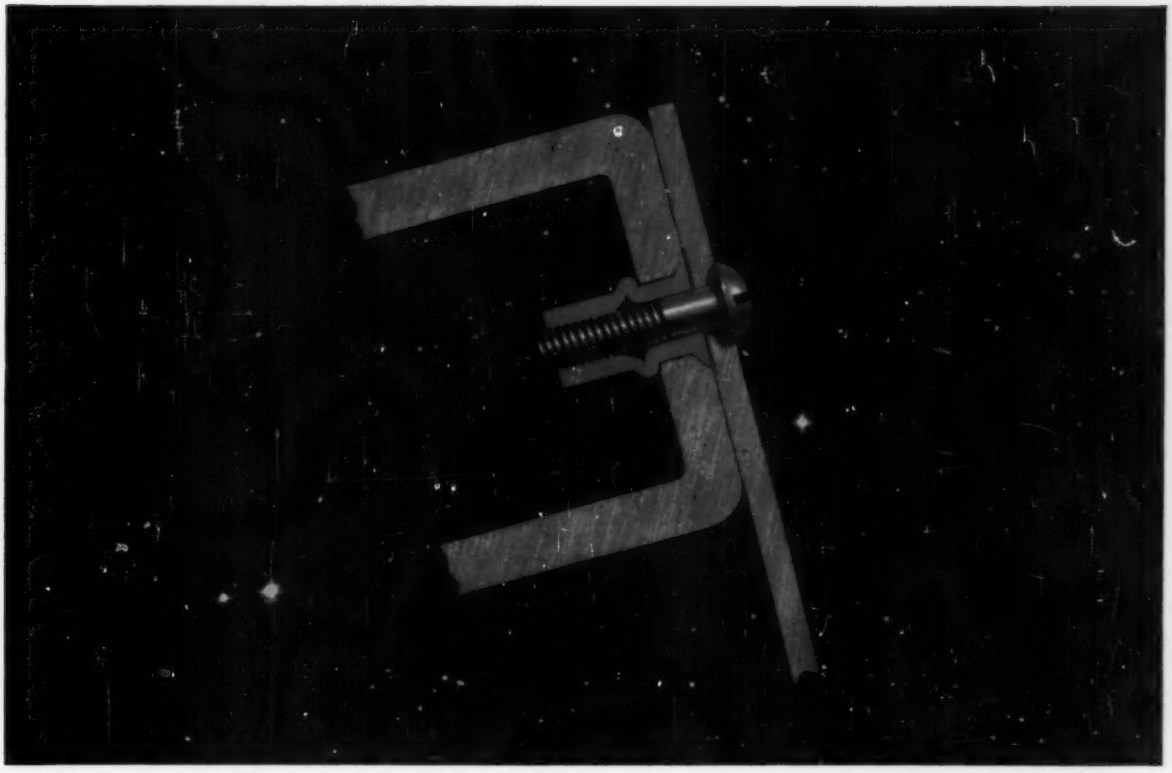
Available in square-flanged receptacle, Q02, and straight plug, Q06. Insert Diameters: 11/64", 11/64", and 13/64"

Designed for control and instrumentation circuits of all types where space, vibration, moisture, or pressure conditions are limiting factors. Resilient grommets seal behind inserts . . . rubber sealing ring seals around the insert faces. Locking engagement accomplished by a beryllium copper latch within a spring loaded sleeve. Three shell sizes, with 7, 13, 19, 37 silver-plated brass 10-amp. contacts for #18 AWG wire. Alternate positioning. Cymel 592 insulators. External parts are cadmium plated aluminum. Hermetically-sealed, round-flanged receptacle, QH25, also available. **Write for Q Miniature Bulletin TODAY!**

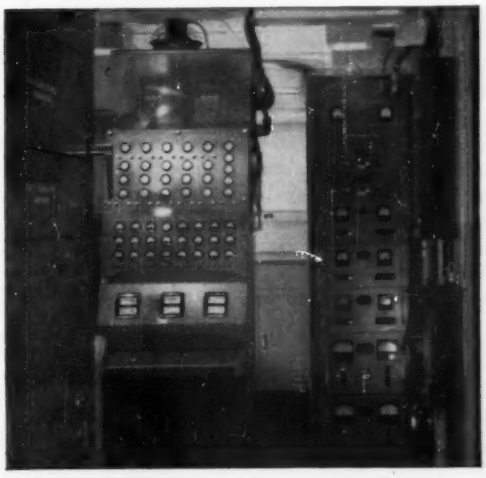
CANNON ELECTRIC CO., 3208 Humboldt St., Los Angeles 31, California.
Factories in Los Angeles, Salem, Mass., Toronto, London, Melbourne.
Manufacturing licensees in Paris, Tokyo. Representatives and distributors in all principal cities.

Please Refer to Dept. 185

B.F. Goodrich Rivnuts® help fasten electronic "ears" that track orbits of man-made moons



Rivnuts provide sturdy blind nutplates for ultra-sensitive equipment that will receive radio impulses from Vanguard Satellite



During the International Geophysical Year, scientists will launch the first American satellite, the Vanguard. To track its orbit around the earth, "Minitrack" stations in North and South America will receive radio signals from the satellite itself, magnify them with ultra-sensitive receivers, and relay position information to the Vanguard Computing Center in Washington.

The photograph (left) shows the inside of a "Minitrack" station, with the receiver rack in the center. Fastening the face panels on this rack posed a problem for Bendix Radio Division, manufacturers of the equipment. Because the frame is made of square tubular aluminum for greater strength, ordinary nuts and bolts could not do the job.

Bendix found the answer in B.F.Goodrich Rivnuts, which provided sturdy, blind nutplates, easy and economical to install. Whatever you manufacture, from complex electronic equipment to simple sheet metal assemblies, B. F. Goodrich Rivnuts may be the answer to your most puzzling fastening problems.

Write for free Rivnut demonstrator, Dept. MD-18

B.F.Goodrich

B.F.Goodrich Aviation Products

a division of The B. F. Goodrich Company, Akron, Ohio

Circle 440 on Page 19

4000 psi

Now Available

VICKERS®

Airborne Variable Displacement Piston Type Pumps

A NEW LINE of Vickers Variable Displacement Piston Type Pumps is now available for aircraft applications at *4000 psi pressure.* These new pumps have the same exceptionally high overall efficiency as well as the many other performance advantages demonstrated by the 3000 psi Vickers pump series throughout millions of hours of dependable airborne service. Flow characteristics and maximum recommended speeds are also the same for both series.

An important feature of the 4000 psi series is a CONTAMINANT-TOLERANT DESIGN enabling successful operations in hydraulic fluids and engine lubricating oils with particle sizes up to 40 microns.

Operation of airborne hydraulic systems at 4000 psi is finding increasing favor because it means smaller actuators and less fluid in the system . . . resulting in an overall weight and space advantage.

Vickers 4000 psi hydraulic motors and fixed displacement pumps will also be available. For further information about 4000 psi pumps and motors, please write for Bulletin A-5219 or get in touch with the nearest Aero Hydraulics Division office listed below.

7880

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

Aero Hydraulics Division • Engineering, Sales and Service Offices:

ADMINISTRATIVE and ENGINEERING CENTER
Department 1430 • Detroit 32, Michigan

TORRANCE, CALIFORNIA • 3201 Lomita Boulevard
P.O. Box 2003 • Torrance, California

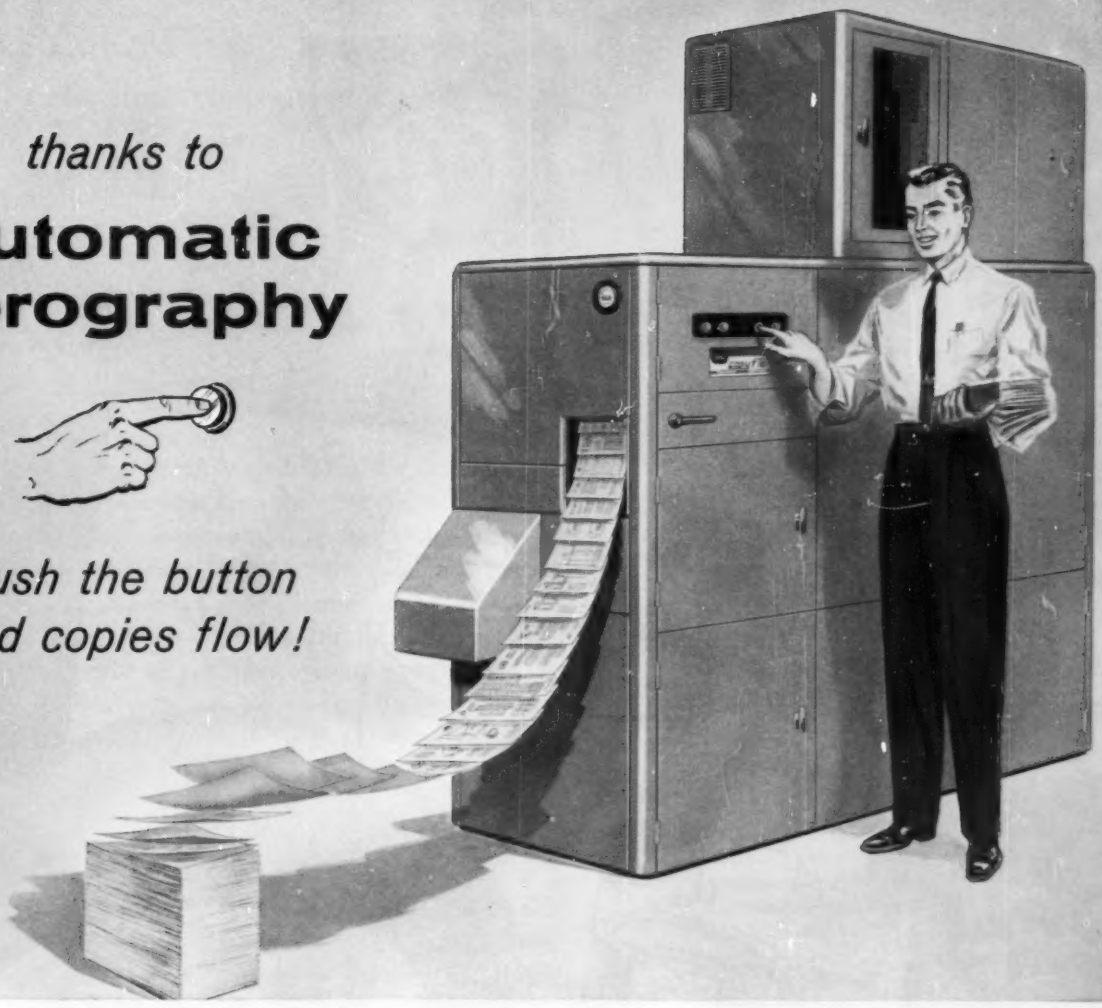
Aero Hydraulics Division District Sales and Service Offices • Albertson, Long Island, N. Y., 882 Willis Ave.
Arlington, Texas, P.O. Box 213 • Seattle 4, Washington, 623 8th Ave. South • Washington 5, D.C., 624-7 Wyatt Bldg.
Additional Service facilities at: Miami Springs, Fla., 641 De Soto Drive
TELEGRAMS: Vickers WUX Detroit, TELETYPE: "ROY" 1149—CABLE: Videt
OVERSEAS REPRESENTATIVE: The Sperry Gyroscope Co., Ltd.—Great West Road, Brentford, Middx., England

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

thanks to

automatic xerography

push the button and copies flow!



XeroX® COPYFLO® Continuous Printer... *fast... clean... versatile... economical*

copies from microfilm or original documents at 1200 feet an hour

The Copyflo Continuous Printer turns out beautifully clear, right-reading prints of engineering drawings, letters, charts and other documents—4 to 11 inches wide and each precisely like the original—on plain unsensitized paper, transparent vellum or offset paper masters, at the rate of 20 feet a minute. This is the equivalent of a full 8½" x 11" copy every two seconds.

The Copyflo Continuous Printer represents a revolutionary advancement in the universally accepted, dry, electrostatic, photo-exact process of xerography.

In the Copyflo unit the xerographic process is continuous and automatic, incorporating all steps in one complete cycle.

Available in three models for specific applications.

Copyflo Model No. 1. Reproduces single copies continuously, up to 11" wide, from 35mm or 16mm roll microfilm.

Copyflo Model No. 2. Reproduces single copies of translucent or opaque originals, at ratios from 46% to 200% of original, to a maximum copy width of 11".

Copyflo Model No. 3. Combines all features of Model No. 1 and Model No. 2 and is interchangeable from microfilm to original document operation and vice versa by a single control lever.

WRITE for further information about the Copyflo Continuous Printer—the new dimension in copying from originals or microfilm.

THE HALOID COMPANY
58-180X Haloid Street, Rochester 3, N. Y.
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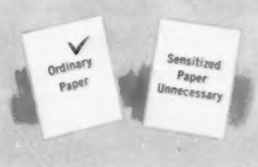
HALOID XEROX®

Copy 1200 **different** documents per hour—a print in about 2 seconds.

Each copy precisely like the original, reduced, enlarged or same size.



Made on ordinary unsensitized paper, vellum or offset paper masters.

Low cost—proven savings to 70% . . . as much as $100,000 a year.

Circle 442 on Page 19

IMPROVE DESIGN

Molded by Plax Corp.

BAKELITE BRAND POLYETHYLENE is used to make this squeeze bottle for the new Ipana Plus dentifrice. This dramatic departure from the conventional is typical of the possibilities of BAKELITE BRAND Plastics. Design advantages include full-range flexibility, simplicity of molding, improved functional performance and attractive finish that is pleasant to touch. Write for technical information.

BAKELITE PLASTICS BRAND ... do so much – so much better!

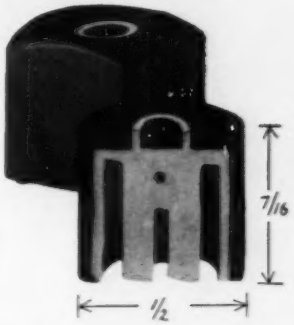
WITH BAKELITE BRAND PLASTICS

Choose from the widest variety of plastics with versatile properties for design excellence

For your next design problem go beyond the limitations of ordinary materials. Give your ideas the same chance for success that these well-designed products have had with BAKELITE BRAND Plastics and Resins. Whether it is a consumer or an industrial problem, there is a wide selection of plastics at your disposal . . . plastics of the highest quality and uniformity . . . all at one convenient source. Their versatile properties offer countless combinations for new design opportunities that lead to better products at better costs.

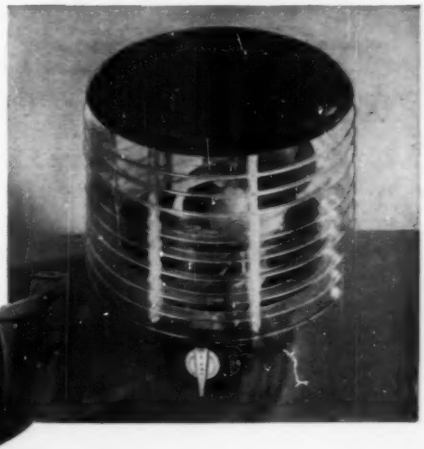
So—*don't make a design decision* until you have explored the proven advantages of BAKELITE BRAND Plastics and Resins . . . advantages that have improved style, color, finish, function and fabrication.

Bakelite Company will help you. Write for the latest technical literature. And remember, the skill and experience of BAKELITE Technical Representatives are at your service for special design problems. Their recommendations are backed by one of the largest research laboratories in the world. Write Dept. MD 1-47.



BAKELITE BRAND C-11 PLASTIC forms this "IBM" Electric Typewriter Key. Typical of the intricate design possible in small items with BAKELITE BRAND Plastics. Molded with "double-shot" technique . . . fine detail retained and overall cost cut. Colorful key has a beautiful, long-lasting finish that resists staining. Write for technical information.

Keys molded by American Plastics Corporation.



BAKELITE BRAND BMG-5000 PHENOLIC gives necessary impact strength and lasting beauty to top and base of this "Air Flight" Electric Fan Hassock. Formulated to take abuse, BMG-5000 has excellent molding characteristics—especially for thick sections and large moldings. It is also noted for its attractive appearance, high gloss, smooth surface finish, richness of color and superior electrical properties. Write for technical information.

Phenolic parts molded by Cambridge—Panelyte Molded Plastics Company, a subsidiary of St. Regis Paper Company.

IMPACT STYRENES
POLYETHYLENES
C-II STYRENES
PHENOLICS
STYRENES
EPOXIES
VINYLS

Products of UNION CARBIDE *Corporation*

BAKELITE COMPANY, *Division of Union Carbide Corporation,* 30 East 42nd Street, New York 17, N. Y.

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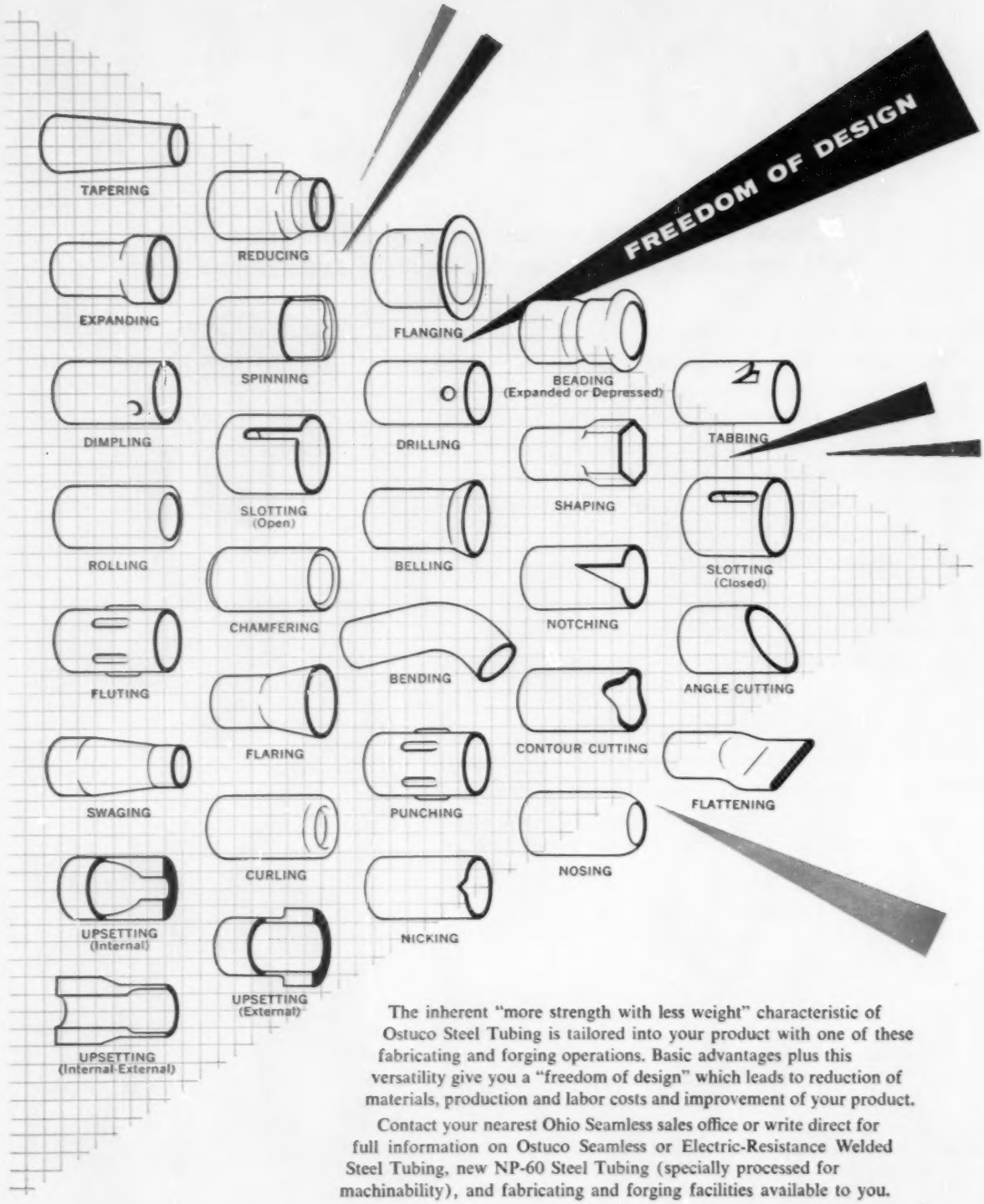
Circle 443 on Page 19



The inherent "more strength with less weight" characteristic of Ostuco Steel Tubing is tailored into your product with one of these fabricating and forging operations. Basic advantages plus this versatility give you a "freedom of design" which leads to reduction of materials, production and labor costs and improvement of your product.

Contact your nearest Ohio Seamless sales office or write direct for full information on Ostuco Seamless or Electric-Resistance Welded Steel Tubing, new NP-60 Steel Tubing (specially processed for machinability), and fabricating and forging facilities available to you.

OSTUCO TUBING

MANUFACTURED IN

SHELBY, OHIO

EXCLUSIVELY BY

OHIO SEAMLESS TUBE DIVISION

OF COPPERWELD STEEL COMPANY

SHELBY, OHIO • Birthplace of the Seamless Steel Tube Industry in America

SEAMLESS AND ELECTRIC-RESISTANCE WELDED STEEL TUBING • FABRICATING • FORGING

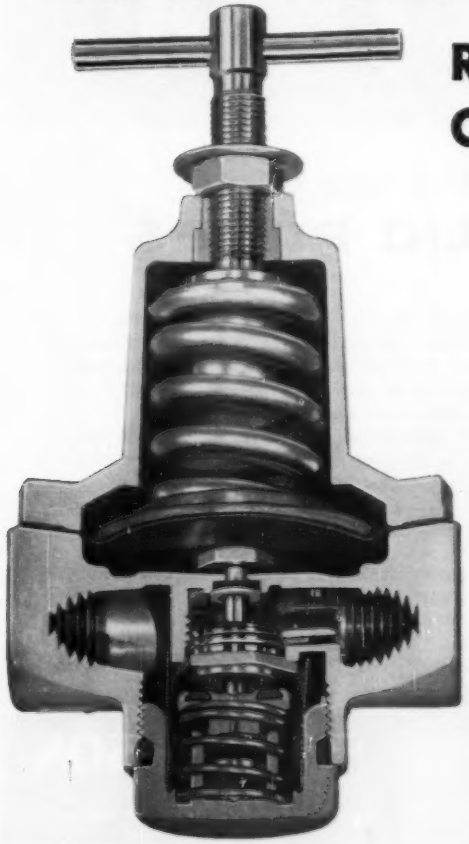
SALES OFFICES: Birmingham • Charlotte • Chicago (Oak Park) Cleveland • Dayton • Denver • Detroit (Ferndale) • Houston Los Angeles (Lynwood) • Moline • New York • North Kansas City • Philadelphia (Wynnewood) • Pittsburgh • Richmond Rochester • Salt Lake City • Seattle • St. Louis • St. Paul St. Petersburg • Tulsa • Wichita

CANADA: Railway & Power Engr. Corp., Ltd.

EXPORT: COPPERWELD STEEL INTERNATIONAL COMPANY, 225 Broadway, New York 7, New York

FACTS about Norgren PRESSURE REGULATORS

Norgren Pressure Regulator on punch press at Shwayder Brothers, Inc., maker of Samsonite Luggage.



Reduce Air Costs . . . Cut Maintenance Costs

For any air operated equipment, there is one pressure at which it is designed to operate most efficiently. Above that pressure, equipment will wear excessively with no significant increase in output, and compressed air will be wasted. No matter what the application, you can choose a Norgren Pressure Regulator that will reduce line pressure to the desired working pressure. Results will include longer equipment life, lower maintenance costs, less down-time and savings in compressed air costs.

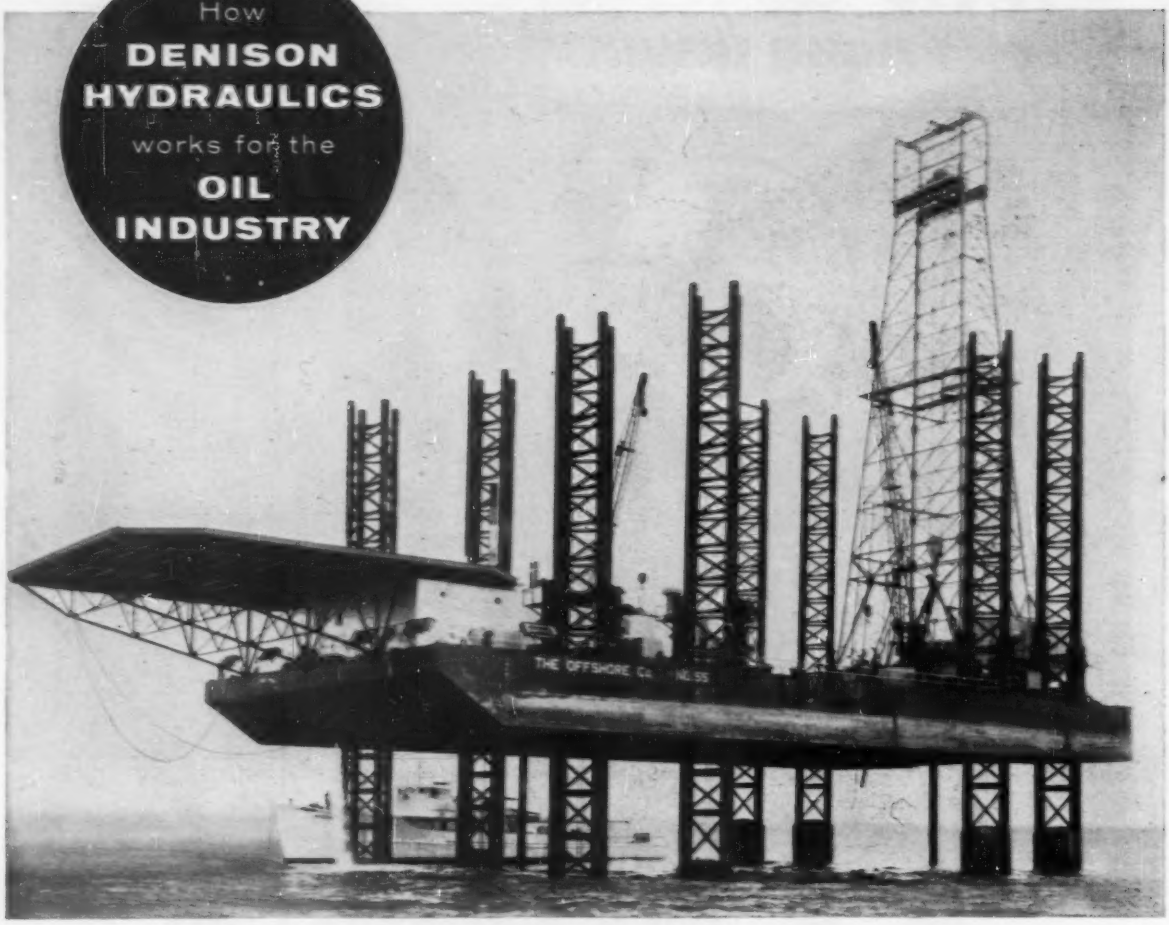
- **Norgren Pressure Regulators are Highly Accurate** over a wide operating range.
- **Regulated Pressure is Held Constant** even with widely fluctuating line pressure and rapidly varying air flow.
- **Flow Capacity is Large**—a. Balanced valve construction; b. Large effective diaphragm area; c. Improved baffle and siphon performance; d. Large passages; e. Large valve openings.
- **Choice of Relieving or Non-Relieving Regulators.**

For complete information on all your regulator needs 1/8" to 2" inclusive, call your nearby Norgren Representative listed in your telephone directory —or WRITE FACTORY FOR NEW No. 900 CATALOG.

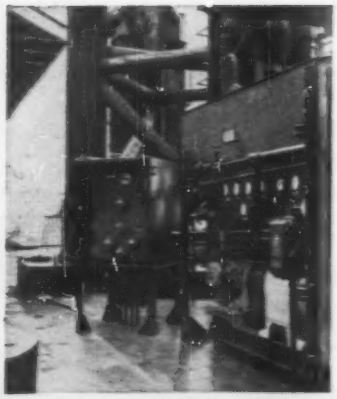
C. A. NORGREN CO.

3442 SOUTH ELATI STREET • ENGLEWOOD, COLORADO

How
DENISON HYDRAULICS
works for the
OIL INDUSTRY



Lifts 6000 tons out of the sea with
DENISON HYDRAULIC PUMPS



***Actuating System Controls** for raising and lowering heavy off-shore rigs built by DeLong Corporation, New York. Denison axial piston pumps actuate hydraulic jacking cylinders, separately or in unison.*

When The Offshore Company faces the problem of raising its 6000-ton DeLong drill barges, they rely on Denison axial piston pumps to deliver the necessary muscle. Rated at 5000 psi continuous duty, four Denison pumps lift the 6000-ton platform at rates up to 15 feet per hour . . . with precision control from one central source.

Utilizing a Series 800, 35 gpm Denison pump at each corner, the hydraulic system developed by DeLong and built to specifications by Denison is capable of actuating lifting jack cylinders separately or in concert as needed. The result is close regulation of the massive 6000-ton load through a system of 16 individual hydraulic jacks on 8 caissons or towers.

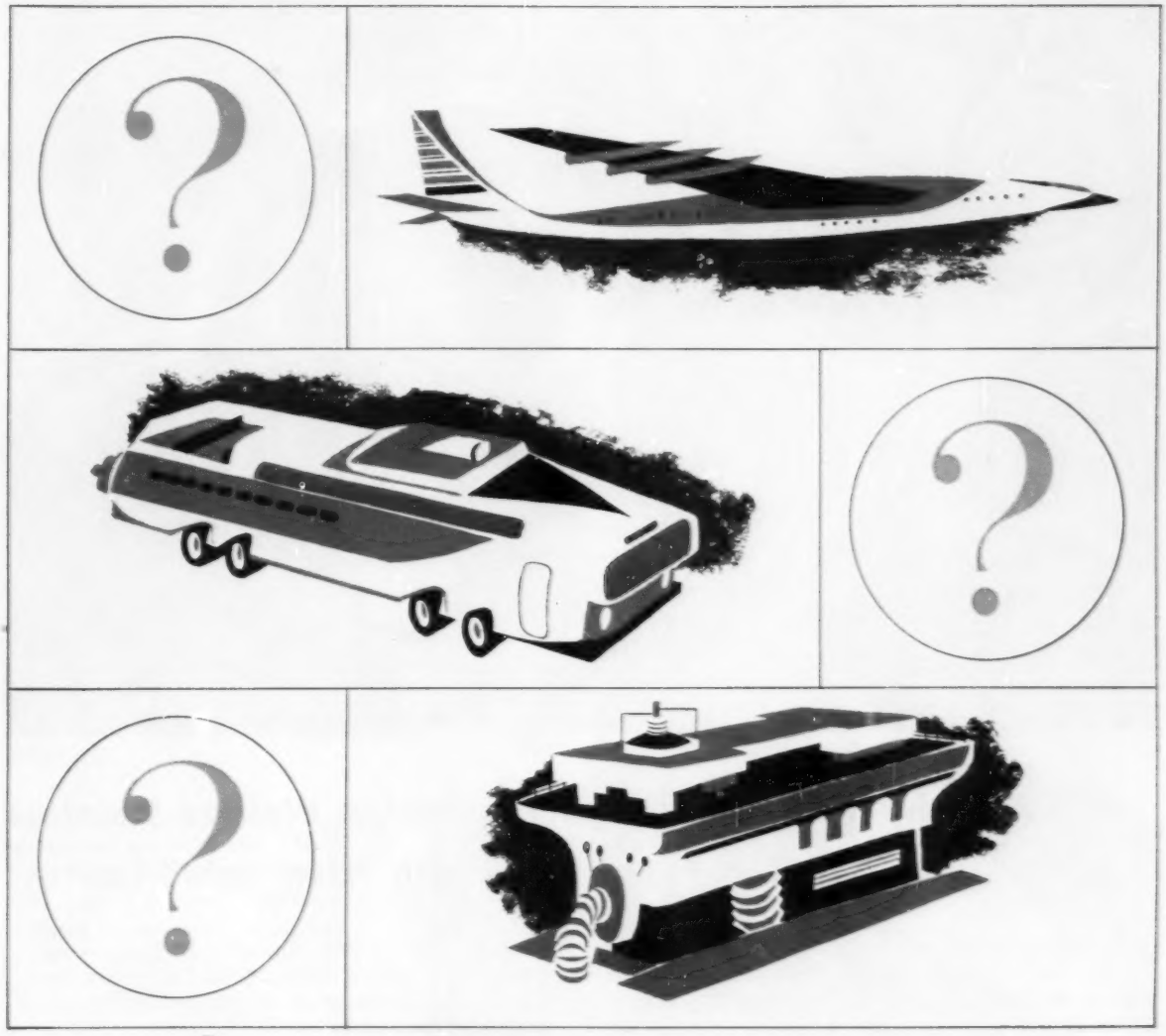
Whatever your actuating problem, Denison can help you develop an efficient hydraulic system to do the job dependably and at low cost. Why not consult Denison on your next job. No obligation. Write us. Denison Engineering Division, American Brake Shoe Co., 1240 Dublin Road, Columbus 16, Ohio.

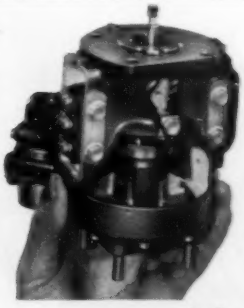
Denison and Denison HydrOILics are registered trademarks of Denison Eng. Div., ABSCO

DENISON HydrOILics

HYDRAULIC PRESSES • PUMPS • MOTORS • CONTROLS

do you need switches set off by speed





Now, a speed sensing control has been produced by AC to trigger up to four turbine engine functions at speeds ranging from 500 to 4600 rpm—within a tolerance of ½ of 1%. No other speed switch now being produced can surpass this AC development for sensitivity and accuracy.

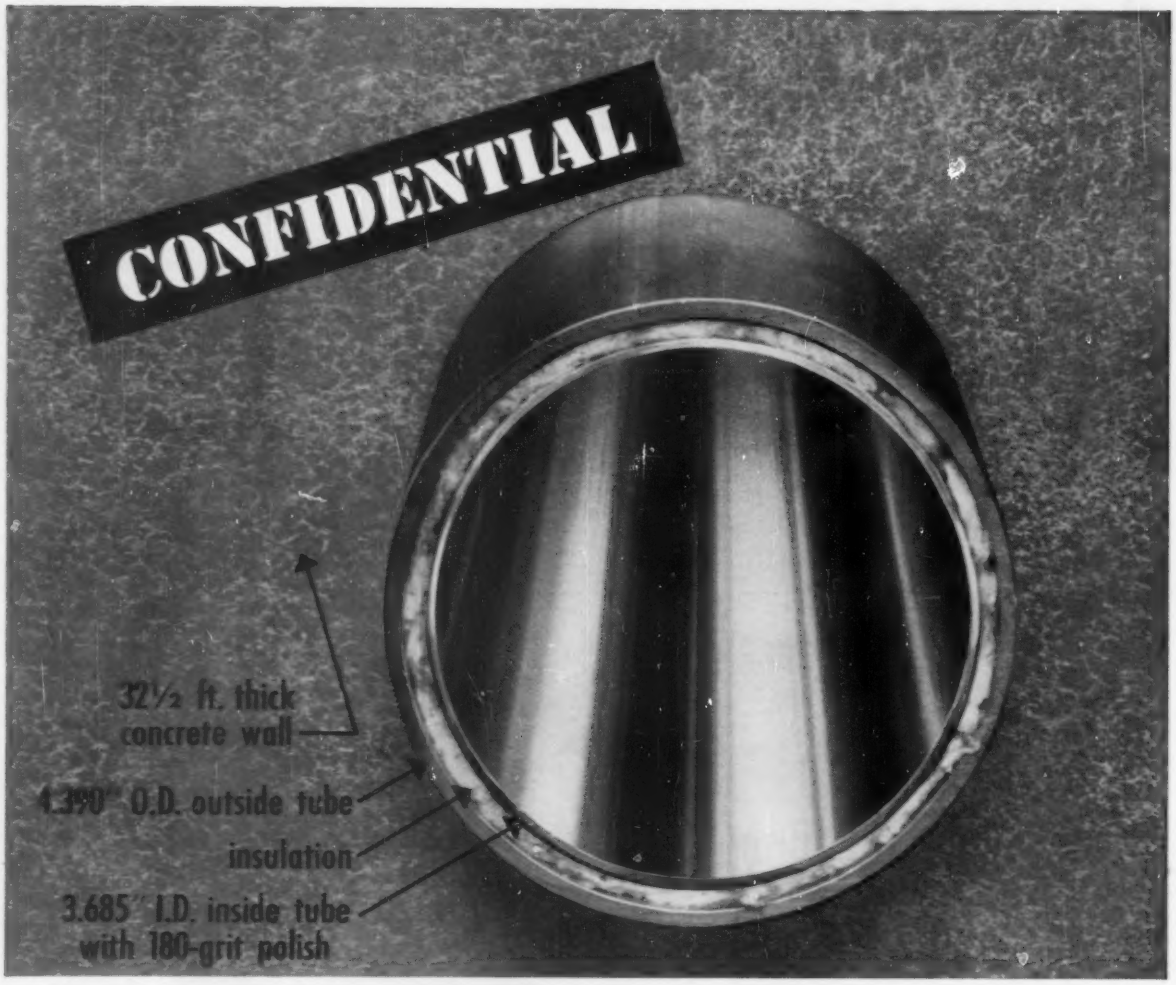
Yet, the AC Speed Sensing Control is light and compact—weighing approximately four pounds. It can be mounted anywhere and is sturdily built to withstand high engine vibration without losing calibration. It will function without attention for longer time intervals than the usually recommended jet engine overhaul period.

Call AC's Milwaukee plant if you have any need for automatic control of switching operations related to speed.

—Or, if you hold a degree in electrical or mechanical engineering, and think you might like to work with AC in Milwaukee, write Mr. Cecil Sundeen, Supervisor of Technical Employment, Dept. C, 1925 E. Kenilworth, Milwaukee 1, Wisconsin.

AC ... THE ELECTRONICS DIVISION OF GENERAL MOTORS

Afterburner Fuel Controls • Bombing Navigational Computers • Emergency Fuel Controls • Gun-Bomb-Rocket Sights • Gyro-Accelerometers • Gyroscopes Inertial Guidance Systems • Manifold Air Pressure Regulators • Speed Sensitive Switches • Speed Sensors • Three-Way Selector Valves • Torquemeters



Proof why it pays to design *Carpenter* Welded Stainless Tubing into tough spots with "skin-tight" limits

Unusually close dimensional tolerances were required by the AEC on nearly 500 ft. of Carpenter Stainless Tubing now being used in the development of nuclear power reactors. The tubing of two different diameters is installed as shown by the above illustration through a 32½ ft. thick concrete wall. Temperature inside the tubing during operation ranges between 1600°F and 2000°F.

The outside tubing was produced within these close limits: 4.390" O.D. (+.000/−.025) ×4.100" I.D. (+.040/−.000); the inside tubing tolerances were: 3.830" O.D. (+.000/−.030) × 3.685" I.D. (+.040/−.000).

Let us demonstrate for you this same ability to produce uniform high quality corrosion and heat-resistant tubing to the tightest specifications. Call in your nearby Carpenter Distributor or Representative for a discussion of your needs.

MEMBER

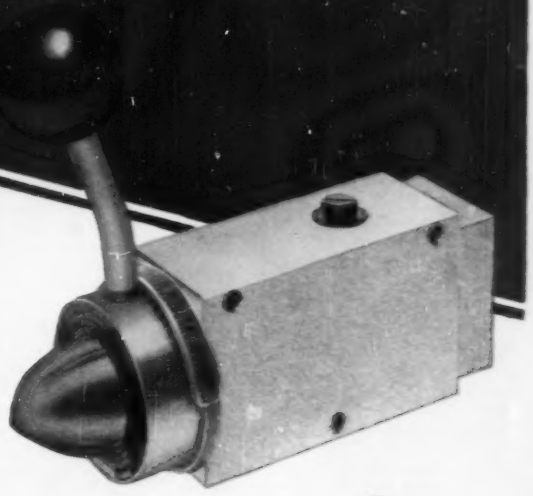
The Carpenter Steel Company
Alloy Tube Division, Union, N. J.

Export Dept.: The Carpenter Steel Co., Port Washington, N. Y.—"CARSTEELCO"

Carpenter

Stainless Tubing & Pipe

For SAFE, DEPENDABLE ENGINEERED for DURABILITY... CONTROLS



CONSULT WATERMAN

Waterman controls are known for their accuracy, dependability, safety, and low maintenance cost.

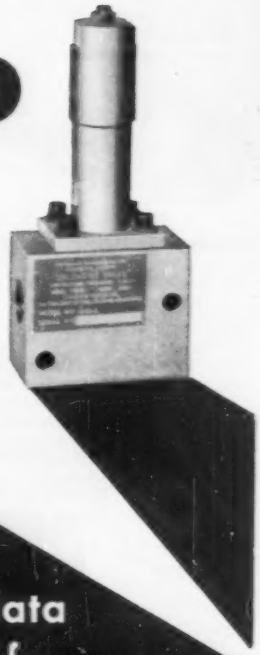
Adjustable Flow Regulators range from 0.5 GPM to 20 GPM. They maintain a constant rate of flow regardless of resistance or pressure fluctuations.

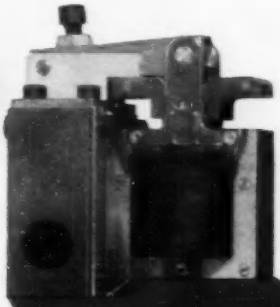
No. 1 Check Valves are one piece, Nylon Poppet, aluminum body and low pressure drop.

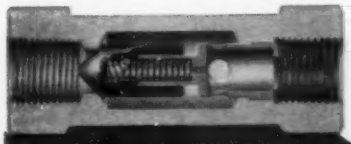
No. 2 Micronic Line Filters have operating pressures to 3000 psi, 40 micron filtration, replaceable elements, and are available in ⅜" and ¼" NPT.

No. 3 Solenoid Valves are inexpensive, compactly built units for hydraulic systems handling non-corrosive fluids. Capable of continuous operation for working pressure to 3000 psi.

No. 4 Unloading Valves for pressures to 3000 psi. Flo rates to 30 GPM. Fast acting, maintain desired pressure without continuous readjustments.







Send for Bulletin E

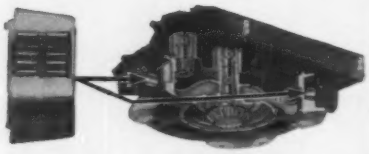
Write for data on any of these WATERMAN products

WATERMAN ENGINEERING COMPANY

725 CUSTER AVENUE EVANSTON, ILLINOIS

BEARING TIPS by McGill

GUIDEROL® bearings add efficiency – and sealing – to greater capacity for THEW LORAIN

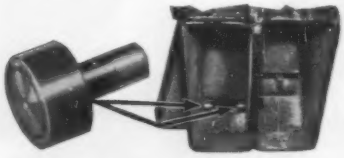


Special GUIDEROL® bearings for turntable rollers

Four of these specially designed turntable rollers support the entire weight of the superstructure plus overhanging work load. They replaced inadequate plain friction rollers to allow for smoother handling of even greater imposed loads with no track wear. Simplified lubrication and longer life reduced maintenance.

Sealed GUIDEROL® bearings for boom peak sheave

The integral seal design of these extra capacity bearings offers exceptional compactness in the Jib and Boom Peak sheaves. Unit costs are lower because counterboring for separate closures are unnecessary. Retained grease in the protected bearings eliminates climbing or lowering the boom for frequent relubrication.



Sealed CAMROL® Cam Followers for outrigger support

Located in the outrigger carrier channels, these cam follower bearings facilitate extending the supporting outriggers. Subject to heavy working loads, these sealed bearings provide low cost and dependable anti-friction support rollers that stay clean and well lubricated.

McGill bearings have the proven quality, design advantages, extra capacity and precision required to insure the efficiency of needle type roller bearings in all modern machinery. They are specified by Thew Lorain to help make the performance of their giant 75 ton Moto-Crane smooth, rugged and reliable under severe operating conditions. Thew Lorain specifies McGILL bearings in all heavy duty equipment for their outstanding dependability with reduced maintenance. McGill bearings will work equally well for you. Write for Catalog No. 52-A.

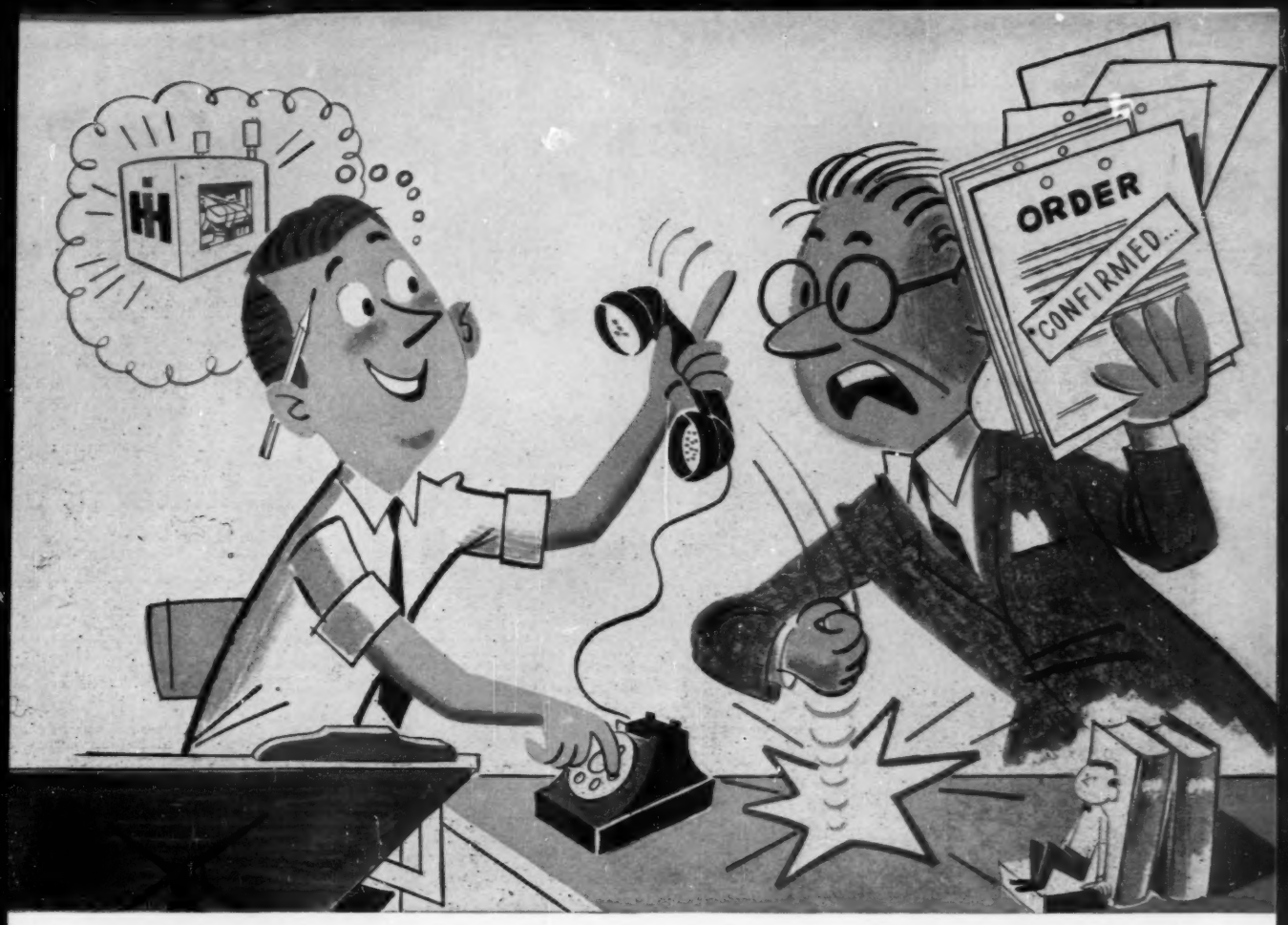
Sealed GUIDEROL® bearings for fairlead sheave

Fairlead sheaves at the base of the boom on drag lines and back hoes, etc. need bearings protected from contamination. Effective sealing against ever present dirt and grit materially extends bearing life.

Insure performance with McGILL®

MULTIROL® GUIDEROL® CAMROL®
Precision Needle Bearings

McGILL MANUFACTURING COMPANY, INC., 200 N. LAFAYETTE ST., VALPARAISO, INDIANA



What to do when your "baby" develops sales appeal overnight

Don't push the panic button. Call THE MAN FROM INTERNATIONAL for very special delivery service of very special product power

Naturally, you should be very proud when your new pilot model performs exactly the way you hoped it would when you finalized the blueprints. But your product plans should also provide for ways of supplying the sales department with prompt production when the sales manager tells you your "baby" has developed terrific sales appeal, almost overnight.

This isn't the time to press the panic button. It's time to call in THE MAN FROM INTERNATIONAL. You can count on him to help you out of any tight spot, especially one like this. He can provide very special delivery service on dependable International engines sized and powered not only for your pilot models but also for quantity production. He sells 20 diesel and carbureted engines you can put in your product and forget about from a service standpoint. And he can deliver any of them fast.

Give him a ring at his headquarters in Melrose Park, Illinois—Fillmore 3-1800—today. You'll find him extremely helpful in solving any production problem that calls for fine engines delivered without red tape. And you'll find the customer-pleasing power he sells will even make your sales manager happy.

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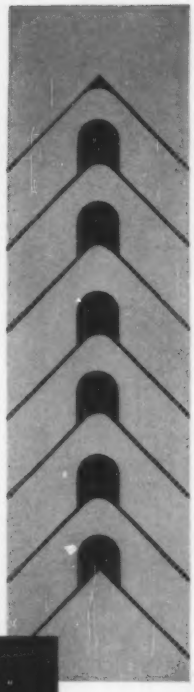

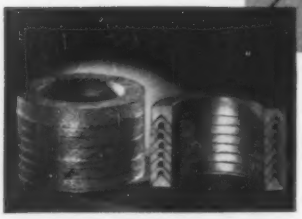

Garlock CHEVRON Packing
Set and cross section

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is a registered trademark of The Garlock Packing Company. It is our responsibility as the manufacturer to see that this trademark is properly used at all times to identify our hinge-type packings. We, therefore, ask that it be used only to designate our product. It should never be used merely as a descriptive or generic term for V-type packings.

CHEVRON Packings are carefully manufactured in Garlock's own factories by experienced craftsmen. Therefore, whenever you see this familiar trademark you can be sure that the packings described will give you long dependable service because they are properly designed and manufactured to the highest quality standards.

Other familiar registered trademarks belonging to Garlock include: BITAN Leather Packings, GUARDIAN Gaskets, KLOZURE Oil Seals, LATTICE BRAID Packings and MECHANIPAK Mechanical Seals. All of these products are sold to you under the Garlock Warranty . . . your assurance that they will satisfactorily perform the service for which they are designed.

THE GARLOCK PACKING COMPANY, Palmyra, N.Y.
For prompt service, contact one of our 30 sales offices and warehouses throughout the U.S. and Canada.

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Mechanical Seal

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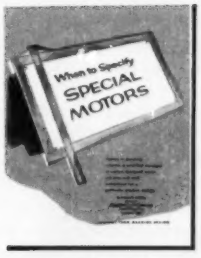
and Grease Seals for Bearings

Garlock LATTICE-BRAID
Rod and Shaft Packings

Need an invisible motor for your product...



FREE! Write for this 24-page booklet. It explains when to specify *Customized* motors, shows examples of design variations, illustrates case histories of *Customized* motors for actual products. Write Jack & Heintz, Inc., 17626 Broadway, Cleveland 1, Ohio.

Call Jack & Heintz—America's leading specialist in *Customized* motors, ⅛ to 5 hp (⅓ to 15 hp in submersible motors). We'll gladly devote as much time as it takes to make a motor so integral with your product as to make that motor invisible . . . a motor that *electrically*, *mechanically* and *physically* blends with and fits your product perfectly.

Customizing electric motors to meet the specific requirements of original equipment manufacturers *is our business*. Because we're organized that way, costs are reasonable to make a motor flush with a product or give it a special finish. We can stretch a motor tall, squat it flat, customize it for ambient temperature ratings. Make it submersible. Increase torque, reduce noise. You name it!

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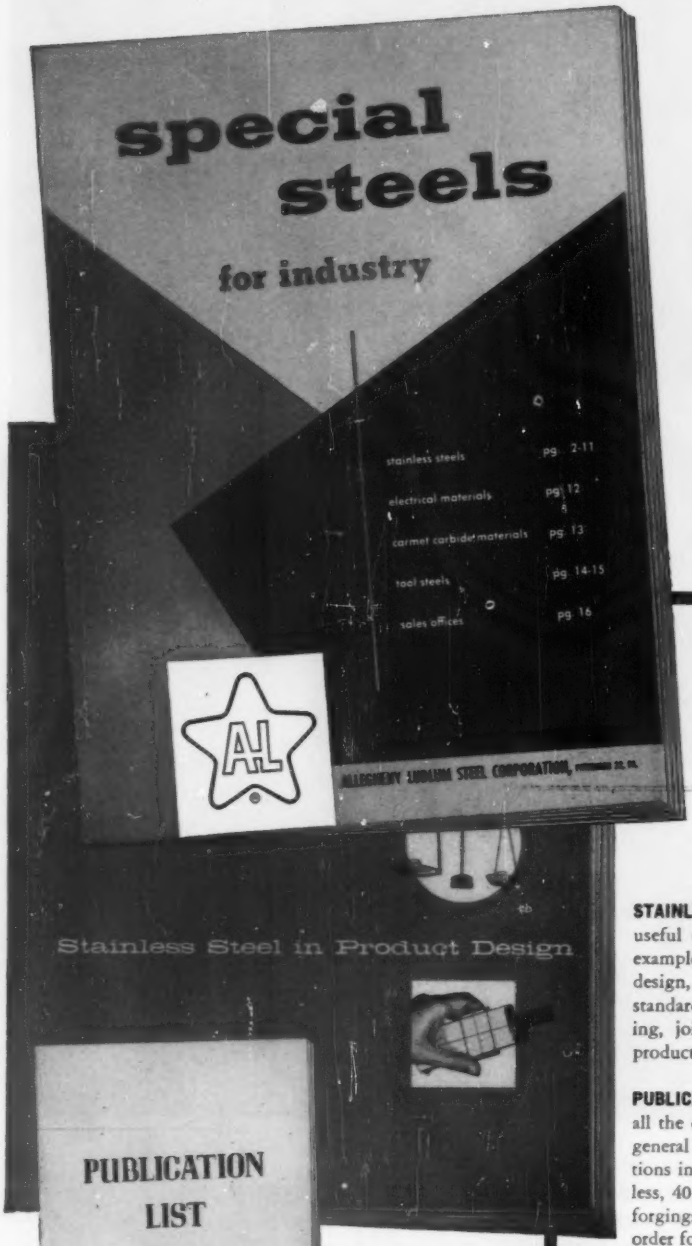
JACK & HEINTZ *CUSTOMIZED* ELECTRIC MOTORS

Circle 453 on Page 19



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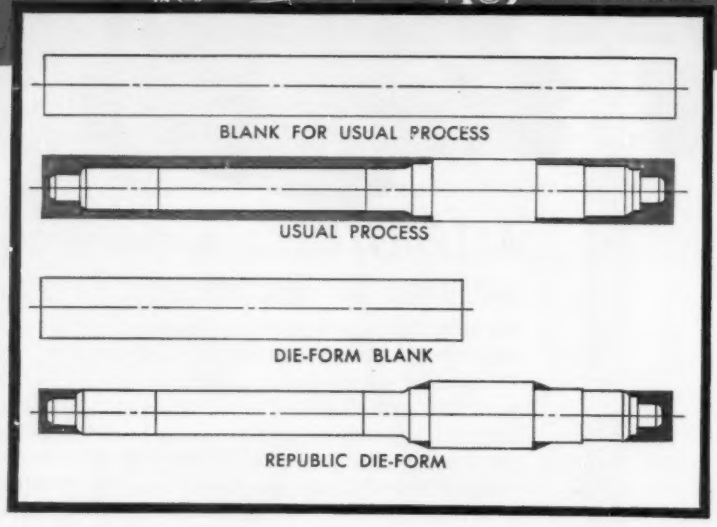
when you specify Republic Die-Form for high-volume production of multi-diameter machine shafts. Drawings and photographs show dramatic savings actually made possible in an automotive transmission shaft. In this case, 200 tons of cold formed blanks produced parts formerly requiring 300 tons. Machining time was reduced accordingly.



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REPUBLIC STEEL

World's Widest Range of Standard Steels

REPUBLIC DIE-FORM

What It Is. The Republic Die-Form process is a new method of cold forming hot rolled carbon, alloy, or stainless steel bars into multi-diameter bars ready for final finishing.

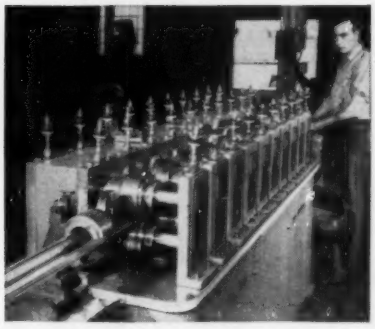
What It Does. Use of Republic Die-Form instead of conventional bar stock permits major savings in time, steel, and money in mass produced, multi-diameter machine shafts. Since Die-Form closely approximates the final part, only finishing cuts and/or grinding are required for completion. Scrap loss is minimized—production rate increased.

Savings in time and steel mean dollar savings. However, costs may be further reduced through decreased capital investment in machine tools, and elimination of excess weight-handling costs in raw material and scrap disposal.

Finally, Republic Die-Form processing increases tensile strength and machinability of any given hot rolled steel analysis used. These characteristics assure an outstanding surface on completed parts, provide further reductions in machining time and permit the possibility of heat treatment elimination.

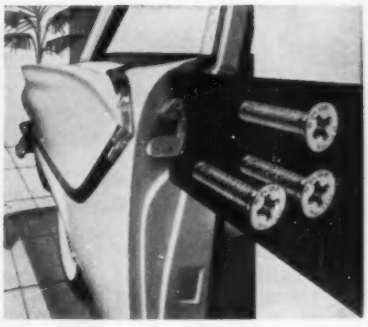
Capacity and Limitations. Republic Die-Form is available up to two inches in diameter. It is limited to symmetrical cross sections of two or more diameters. "Hourglass" sections cannot be produced. Die-Form is economical only in large production runs.

Plan now to check the savings potential of Republic Die-Form in your machined shaft production. Contact your Republic office for full details. Or write for illustrated literature, ADV-746.



SAVE PAINT PREPARATION COSTS on your formed steel products by specifying Republic Electro Paintlok®. Special paint-holding surface is applied at our mills. It won't crack, flake or peel, even under severe bending, as demonstrated by this acoustical fastener forming operation. Final finish can be applied immediately, with excellent results. Mail coupon for data.

TIME, LABOR, AND SPACE SAVINGS were all realized through use of Republic Roll-Over Boxes for this bulk chemical handling operation. Former laborious methods involving bagged material were eliminated. Now one man with revolving-fork truck does the job faster, more efficiently. Check advantages of Republic's complete materials handling line. Send coupon.



LIFESAVING DOOR LATCH striker plate is permanently anchored to door post with Republic Nylok® Bolts. Nylon pellet in body of bolt forces strong metal-to-metal lock between opposite mating threads. Resiliency of pellet provides excellent adjustability and re-use characteristics—and provides liquid seal when bolts are seated. Send coupon for facts.

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Circle 456 on Page 19

SYNCHRON®
TIMING MOTORS

Precision Engineered for Dependable Power

UL and CSA approvals

SYNCHRON synchronous motors operate smoothly, evenly in any position at temperatures from −40° to +140° F., start instantly under load; pull up to 20 in. oz. at 1 RPM. Available in 42 speeds from 0.8 RPM to 600 RPM.

1 **PATENTED TWO-PIECE FIELD STRUCTURE** having wide and narrow poles, with rotor that rotates between inner and outer field poles. The inner and outer poles are properly shaded with heavy, continuous copper rings to assure maximum starting and running torque.

2 **DOUBLE BEARINGS** in reduction train on rotor shaft assure smooth operation.

3 **ALUMINUM ROTOR RING SUPPORT.**

4 **PATENTED, HARDENED STEEL ROTOR RING.**

5 **OIL STORAGE RESERVOIR** with patented oil feed to bearings.

6 **HEAVY BRASS ROTOR COVER.**

7 **DOUBLE BEARINGS ON OUTPUT SHAFT.**

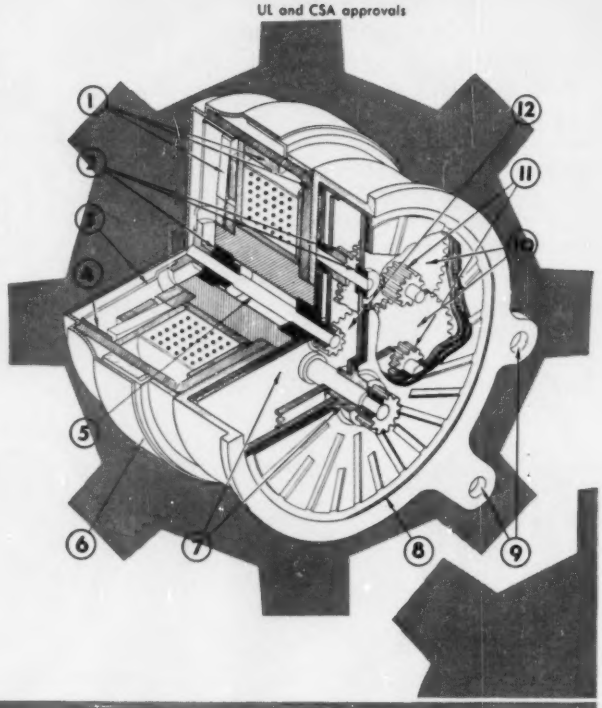
8 **GEAR CASE SEALED** against oil leakage to permit mounting in any position.

9 **FOUR CONVENIENT MOUNTING HOLES.**

10 **BRASS GEARS.**

11 **STEEL PINIONS.** Note: Brass against steel assures longer life.

12 **BAKELITE GEAR** for quiet operation.



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There's big power packed into this versatile timing motor. One year guarantee. Dependable, accurate, trouble-free. Guaranteed torque 20 in. oz. at 1 r.p.m.

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A new timing motor developed especially for slow motion jobs. Guaranteed 20 in. oz. at 1 r.p.h., (1/60 r.p.m.)

HANSEN CLOCK MOVEMENTS
For standard and office clocks, sign clocks, novelty clocks, and clocks of all kinds up to 26" in diameter under glass. Precision power with a Synchron timing motor.

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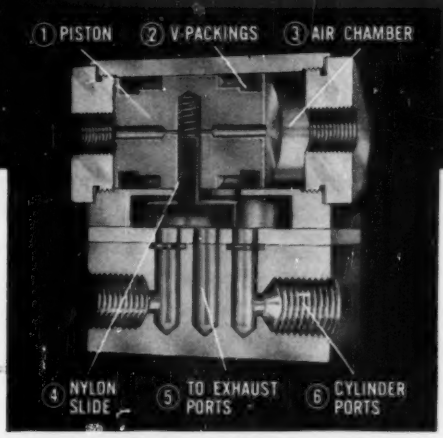


Diagram shows air flowing to one side of a double acting cylinder from outlet 6 while being exhausted through hole 5 on other side of cylinder. When the right poppet is touched, air is bled from chamber 3 and piston(1) is shifted to right. At this point, air is exhausted through port 6 as air enters opposite side of cylinder.

Here at last is the air valve which makes "automation with air power" absurdly simple. No expensive, delicate electrical circuits are needed! It's air pressure alone—distributed through slender, flexible hose—that does the work with the same instantaneous response of electricity.

A light momentary touch on the miniature limit switch actuates the main valve piston, which moves from side to side like a shuttle, clearing first one air passage and then the other. The piston is moved by releasing the air on one side through the limit switch. Regardless of amount of air pressure, a featherweight touch releases air, shifts piston.

The limit valves can be mounted at points where they will be tripped by the moving parts of a working machine, such as the ram of an air cylinder, the moving table of a milling machine, the depth stop rod of a drill press, or a revolving cam on a shaft.

Cost-saving possibilities are almost unlimited! Now clean, quick, dexterous air power can be directly integrated with mechanical functions of many production machines. New worlds open to original equipment manufacturers!

Let us help with your problem. If you have a possible application for **MEADMATIC** valves, timers or cylinders, tell us (confidentially) and we'll try to come up with the answer. Write for Air Power Catalog!

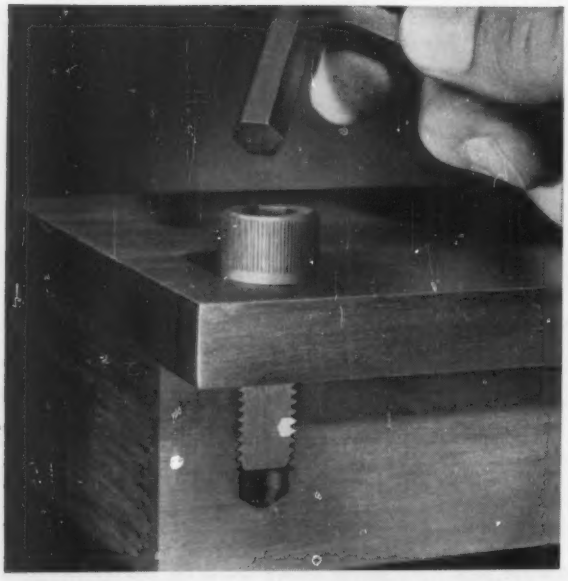
Write today for Air Catalog!

MEAD
SPECIALTIES COMPANY
4114 N. Knox Ave., Dept. MD-18, Chicago 41, Illinois

PATHFINDER IN AIR **POWER AUTOMATION**

The ordinary fasteners securing the worm wheel to the drum shaft in this automatic screw machine loosened, causing $120 worth of damage to parts. Labor for the repair job cost $100. The ordinary fasteners were replaced with self-locking UNBRAKOS, and there has been no trouble since.

Vibration won't loosen self-locking UNBRAKO socket cap screws



HOW IT LOCKS. The tough, resilient Nylok locking pellet keys itself into the mating threads. It forces threads together and locks the screw securely—whether or not the screw is seated.

UNBRAKO socket screws with the Nylok* self-locking device eliminate fastener problems caused by vibration.

Take the drive system in the automatic screw machine illustrated above, for example. The screws originally used to secure the worm wheel to the drum shaft loosened, causing considerable damage, besides loss of production time. These have now been replaced with self-locking UNBRAKO socket head cap screws and the trouble has been eliminated.

An UNBRAKO socket screw with the Nylok self-locking device is a single unit. Just screw it into any tapped hole. Seated or not, it locks positively wherever wrenching stops. Constant vibration or endless running of a machine won't affect these self-locking UNBRAKOS. The screws will not work loose!

Write today for your copy of Form 2193, which gives catalog and technical data on the complete line of UNBRAKO socket screws with the Nylok self-locking device. Or see your local industrial distributor. Unbrako Socket Screw Division, STANDARD PRESSED STEEL CO., Jenkintown 18, Pa.

UNBRAKO SOCKET SCREW DIVISION

STANDARD PRESSED STEEL CO.

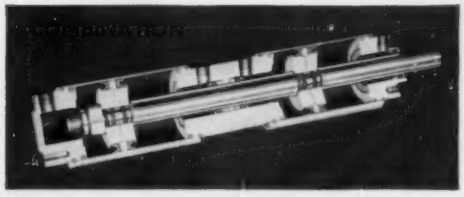
SPS

JENKINTOWN PENNSYLVANIA

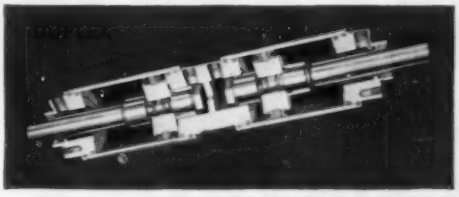
*T.M. Reg. U.S. Pat. Off., The Nylok Corporation

O-M Design Assures Maximum VERSATILITY

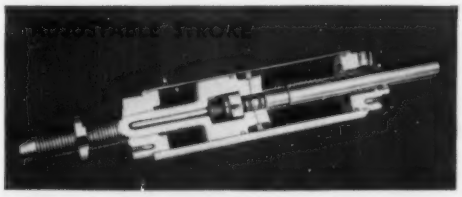
The O-M Internal key-type cylinders are not only the most compact, streamlined and efficient cylinders on the market today; but they also easily lend themselves to modification. Using a majority of standard parts and one or two semi-standard parts, you get the advantages of "special" cylinders designed to do your job better at a very nominal extra over standard cylinder prices. Here are only a few of the combinations available.



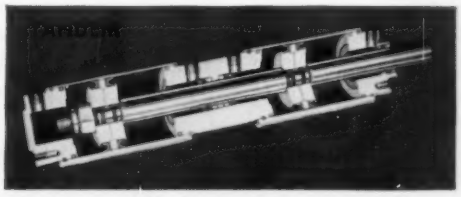
The economy and ease of air operation can be teamed up with the precision of hydraulic speed control. This can be accomplished with the O-M Air-Hydraulic combination cylinder by merely metering the oil flow between the ports of the forward cylinder of the unit.



The duplex cylinder is "just the ticket" for the application where movement takes place in opposite directions in the same plane. Both piston rods may be extended or retracted simultaneously, or independently. Also available with common center port.



Often it is necessary to make frequent changes in stroke length on the same or different jobs on the same machine. This adjustment is easily accomplished with micrometer accuracy in only a moment's time.



When diametrical space is at a premium and the available pressure of the operating medium is low, the force can be almost doubled by the use of the tandem air or low pressure hydraulic cylinder.

Consult your O-M Representative or the factory for specific recommendations for your application. Use coupon for name of representative nearest you and copies of O-M standard cylinder catalogs.

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ORTMAN-MILLER MACHINE COMPANY

7 143rd Street, Hammond, Indiana

☐ Have representative call

☐ Send Bulletins 101A and 105

Name_____ Position_____

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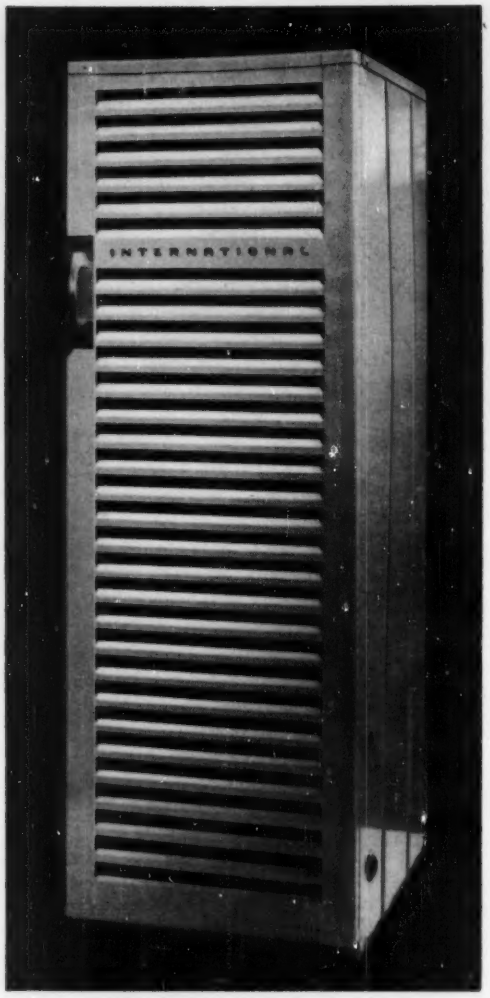
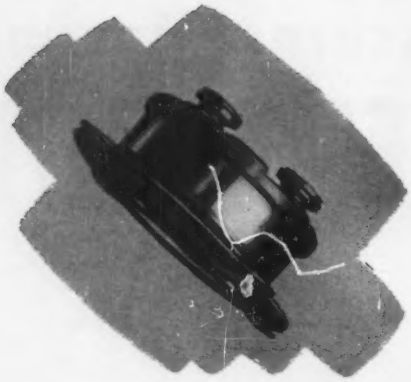




KLIXON

SNAP-ACTING CONTROLS

are designed into International's Mobile Home Furnaces for dependable performance

In developing its automatic central furnace for mobile homes, the International Oil Burner Company, like other leading heating equipment manufacturers, chose KLIXON Controls on the basis of performance.

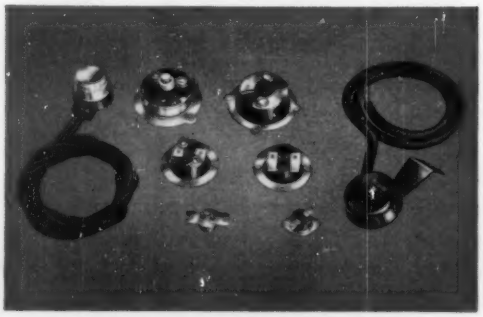
International's TAC 1000, which is compactly designed to fit into mobile home cabinet space and deliver 43,000 BTU/hr., uses KLIXON Controls in hi-limit, low-limit and fan control applications.

The inherent snap-action operation and rugged construction of KLIXON Controls make them especially suited for uses such as this.

Here's what Jordan Heiman, Superintendent of Research for International, has to say about these KLIXON Controls:

"In designing domestic warm air heating equipment, we find our limit applications generally require controls which operate consistently at high temperatures with electrical loads varying from millivolt circuits to high voltage. KLIXON Controls have most often met our specifications."

Designers and manufacturers who seek dependable, trouble-free performance in temperature controls are turning more and more to KLIXON. A wide variety of open and hermetically sealed types of KLIXON Controls are available with fixed temperature settings engineered to meet your requirements. Write today for Catalog THSN.



KLIXON®

METALS & CONTROLS CORPORATION

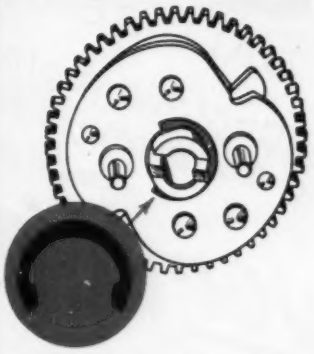
SPENCER THERMOSTAT DIVISION

3201 FOREST STREET, ATTLEBORO, MASS.

Waldes Truarc Rings speed assembly, facilitate maintenance, improve performance of new automatic calculator

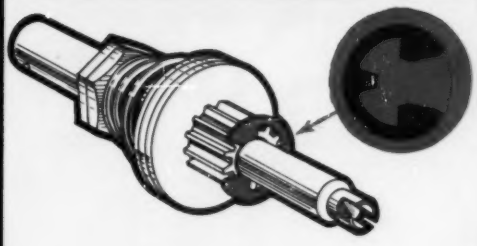
THE NEW MARCHANT DECI•MAGIC

automatic-decimals calculator made by Marchant Calculators, Inc., Oakland, California.

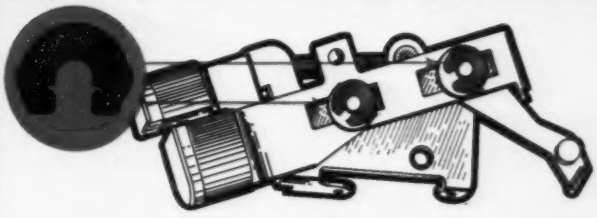


CRESCENT RING SPEEDS ASSEMBLY, DISASSEMBLY

Main clutch utilizes radially-installed series 5103 crescent ring for rapid assembly and disassembly. Ring's low protruding shoulder provides necessary clearance between ring and the two studs. The main clutch operates each time a Deci-Magic control key is depressed.



E-RING SECURES PARTS AGAINST SPRING THRUST. Slip clutch assembly uses Truarc series 5133 E-ring to hold parts on shaft. Functioning of the assembly is dependent upon the ring's ability to withstand thrust exerted by the heavy barrel spring.



LOCKING PRONG RINGS PERMIT SIMPLE DESIGN. Shift slide assembly uses two Truarc series 5139 bowed locking prong rings to lock the parts together in a sliding fit. Precise amount of spring tension prevents objectionable wobble and noise, permits the key to slide smoothly in operation. Easy radial assembly and disassembly of rings facilitates field maintenance and repair. Alternative construction would have required cut washer, spring washer and hairpin-type spring clip on each stud.

Whatever you make, there's a Waldes Truarc Ring designed to save you material, machining and labor costs, and to improve the functioning of your product.

In Truarc, you get

Complete Selection: 36 functionally different types. As many as 97 standard sizes within a ring type. 5 metal specifications and 14 different finishes. All types available quickly from leading OEM distributors in 90 stocking points throughout the U. S. and Canada.

Controlled Quality from engineering and raw materials through to the finished product. Every step in manufacture watched and checked in Waldes' own modern plant.

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Design and Engineering Service not only helps you select the proper type of ring for your purpose, but also helps you use it most efficiently. Send us your blueprints today...let our Truarc engineers help you solve design, assembly and production problems...without obligation.

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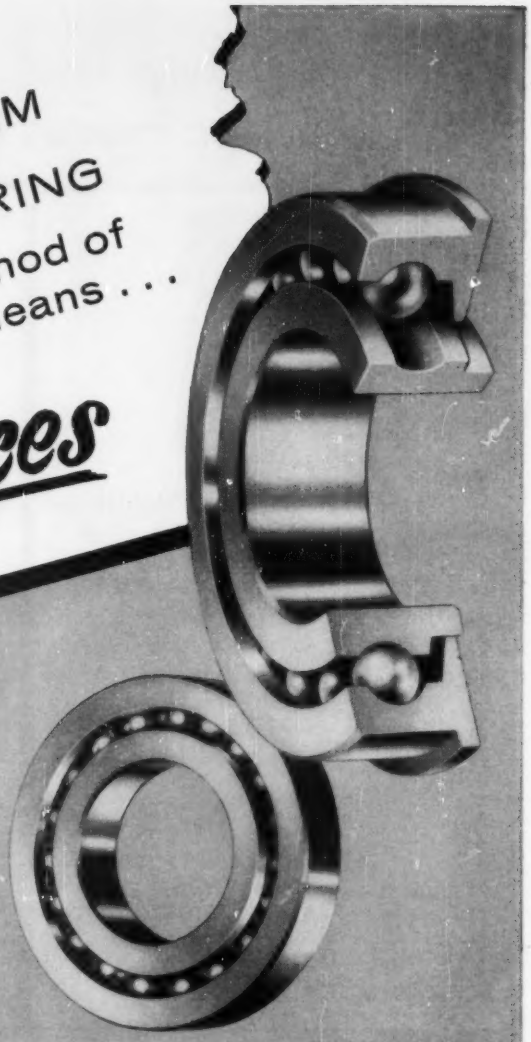
MP010

WALDES TRUARC Retaining Rings, Grooving Tools, Pliers, Applicators and Dispensers are protected by one or more of the following U. S. Patents: 2,382,948; 2,411,426; 2,411,761; 2,416,852; 2,420,921; 2,428,341; 2,439,785; 2,441,846; 2,455,165; 2,483,379; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,491,310; 2,509,081; 2,544,631; 2,546,616; 2,547,263; 2,558,704; 2,574,034; 2,577,319; 2,595,787, and other U. S. Patents pending. Equal patent protection established in foreign countries.

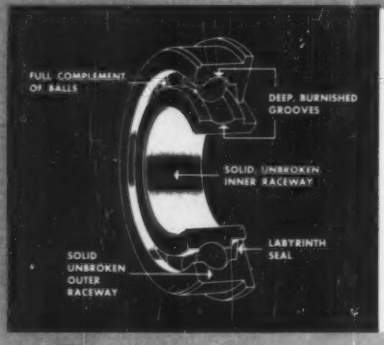
THE NEW HEIM Unibal® BALL BEARING

This new, ingenious method of ball bearing assembly means . . .

Lower Prices



The simplicity of its construction avoids costly, extra assembly devices and results in fewer component parts, which fit together easily to form a smooth running bearing. Unibal is a premium quality commercial ball bearing, delivering superb performance at prices substantially lower than ground ball bearings.



Compared with conventional commercial ball bearings, longer life is attained and both radial and axial load capacities are increased by the sturdy, one-piece raceway construction.

Note this unusual construction (patents pending):

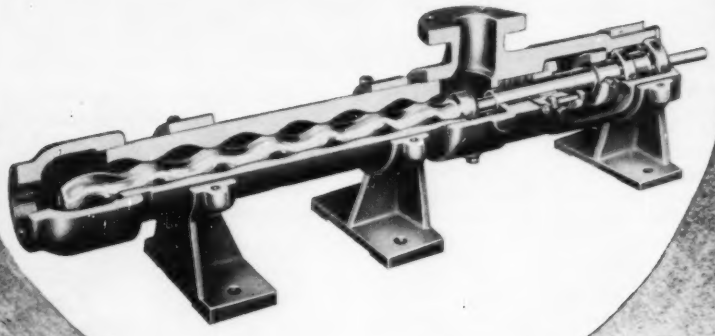
- Solid, unbroken, machined outer and inner raceways.
- Deep, burnished ball grooves with a full complement of balls.
- Both raceways are deep carburized and hardened.
- Labyrinth seals on one or both sides.

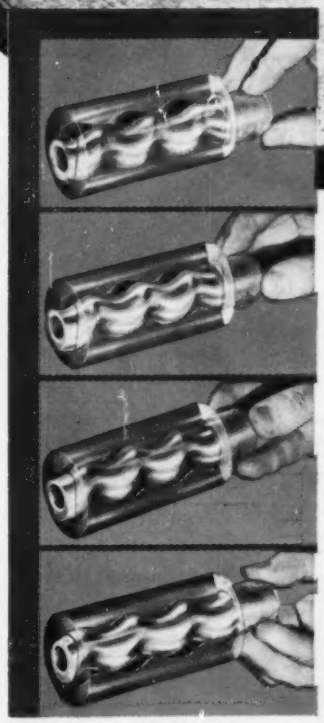
Available in single row, double row, with or without flanges; extremely narrow widths and small diameters; to close tolerances and controlled radial and axial play.

HEIM is also the originator of the Unibal® Spherical Bearing Rod End.
Write for catalog and special bulletin with load ratings and dimensions.

Manufactured by THE HEIM COMPANY for Universal Bearing Corp.
FAIRFIELD, CONNECTICUT

IF IT CAN BE PUSHED THROUGH A PIPE... A MOYNO® WILL PUMP IT!





Moyno's exclusive "progressing cavity" principle permits hundreds of formerly "unpumpable" materials to be handled successfully. The screw-like rotor revolves in a double threaded stator forming "progressing cavities" that move the material smoothly without foaming, aerating, crushing or excessive pump wear.

Typical materials pumped include non-pourable pastes, slurries, chemicals, foods, acids, even suspended solids up to one inch in size. Capacities available up to 500 gpm and pressures up to 1000 psi.

No doubt a Moyno Pump can cut costs drastically for you. *Write for Bulletin 30-MD.*

ROBBINS & MYERS, INC.

SPRINGFIELD, OHIO | BRANTFORD, ONTARIO

MOTORS · FANS · HOISTS · MOYNO PUMPS · PROPELLAIR® FANS

Circle 464 on Page 19

ONE OF A SERIES OF INFORMATIVE MESSAGES FROM HYATT...

How Separable Race Roller Bearings with Interchangeable Parts can Improve Machine Design...

With HYATTS, the designer can increase shaft diameter or reduce housing bore by omitting races... eliminate selective fitting for greater flexibility of assembly operations

The unique advantages of straight cylindrical roller bearings which result directly from the geometry of the bearing itself are quite generally accepted by design engineers. They recognize, for example, that cylindrical roller bearings provide greater radial load-carrying capacity because of the larger area of contact between races and rollers. Most designers are also aware that straight cylindrical roller bearings offer the lowest roller bearing friction characteristics because this type most closely approaches true rolling action.

However, a well-designed line of roller bearings provides additional advantages which are not inherent in the bearing geometry, but result from the engineering know-how of the manufacturer. These benefits are not so widely known and are sometimes overlooked by designers.

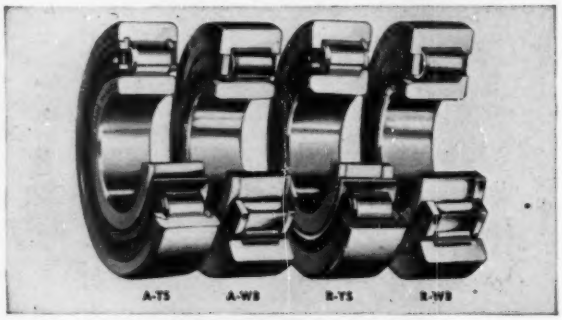
1. INTERCHANGEABLE PARTS PERMIT MORE FLEXIBLE ASSEMBLY

A good example of these "built-in" benefits is the interchangeability of separable bearing parts provided in the HYATT line of cylindrical bearings. Any HYATT Hy-Load Series separable inner race, for a given piece number, can be assembled with any HYATT outer race and roller assembly of the same piece number. Only under special circumstances is there any necessity for selectively matching separable parts of HYATT Hy-Roll Bearings.

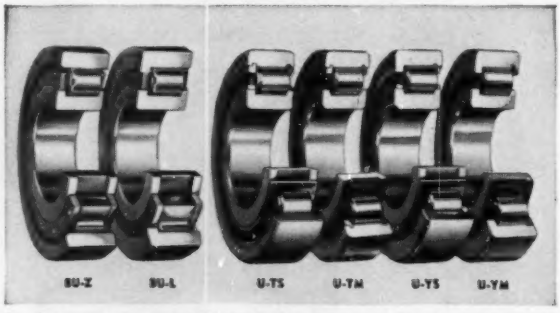
Because of this interchangeability feature, it is practical to install separable HYATT inner races on shafts in one location while the outer races and rollers are installed in housings at another location. When the sub-assemblies are brought together the bearing parts will match perfectly; there is seldom any need for selective assembly. This flexibility of any assembly operation in which selective fitting is eliminated can often be a determining factor in bearing selection.

2. SEPARABLE INNER RACES PERMIT INCREASED SHAFT DIAMETERS

Another advantage of HYATT separable bearings becomes evident when the designer wishes to use a larger, more rigid shaft without increasing the size of the housing bore. He can neatly solve the problem by eliminating the inner race of one of the bearing types shown in Figs. A and D, and operating the bearing rollers directly on the suitably hardened and ground shaft. The space usually occupied by the inner race then becomes available for a shaft of larger diameter.



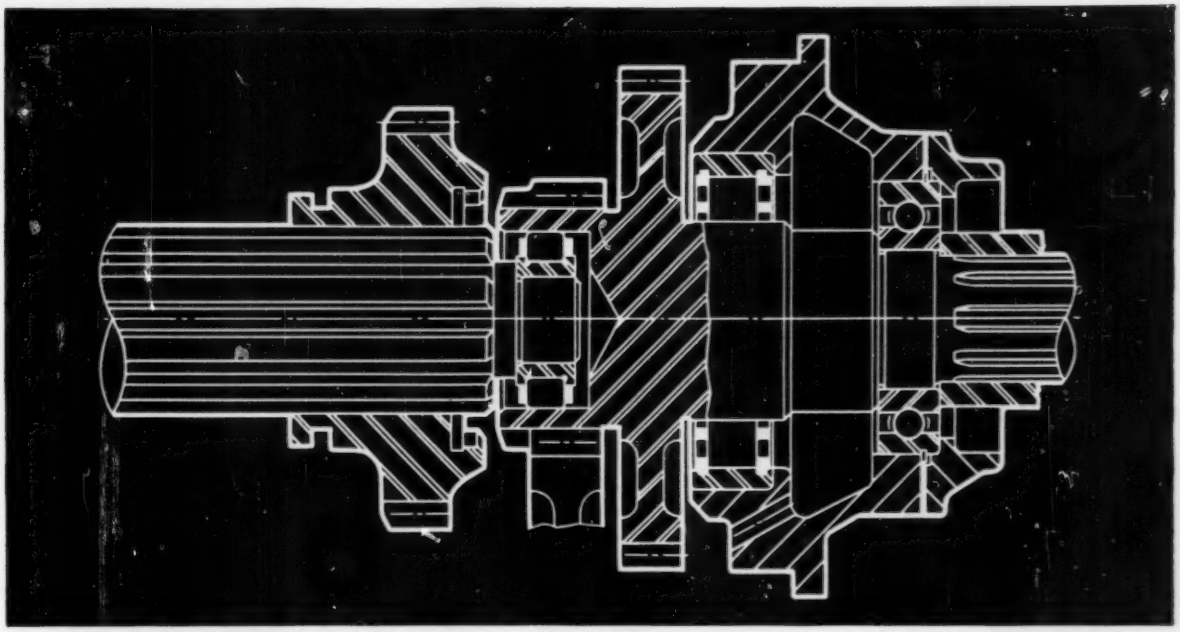
A. Cutaway views of HYATT Hy-Load separable inner race types



B. Cutaway views of HYATT Hy-Load separable outer race types
B-1. Cutaway views of HYATT Hy-Load non-separable types *(right)*

3. SEPARABLE OUTER RACES PERMIT REDUCED HOUSING BORE SIZES

Conversely, when space limitations or other considerations make it necessary to reduce the size of the housing bore without decreasing shaft diameter, HYATT separable bearings are again the answer. In this case, the designer merely eliminates the outer race of one of the bearing types shown in Figs. B and E, and operates the rollers directly on the suitably hardened and ground bore, thus saving the space normally occupied by the outer race. Of course, in applications where it is preferable to retain the bearing parts as a unit, HYATTS are available in non-separable assemblies (Figs. B-1 and F).

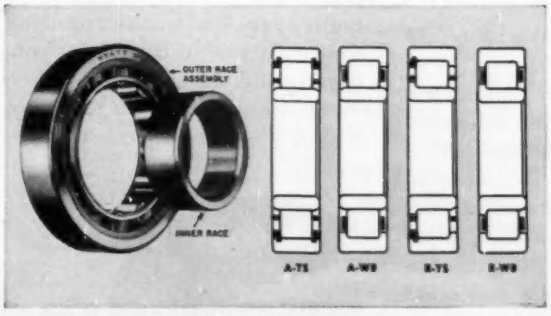


C. Typical transmission application: pilot bearing is BU-Z type without *outer* race, operating directly on hardened and ground gear bore. The A-TS type is used without *inner* race, and operates directly on hardened and ground surface of gear hub.

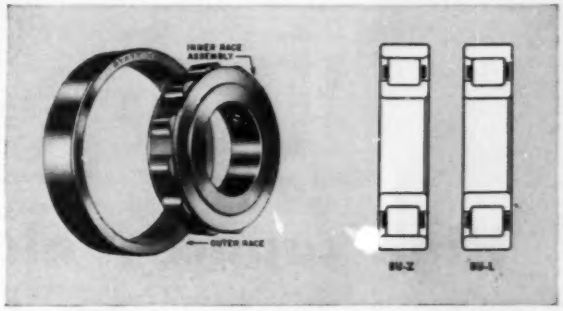
Worthwhile opportunities for improvements such as these in machine design may be overlooked unless designers are familiar with not only the inherent but also the "engineered-in" features of cylindrical roller bearings. So when specifying bearings, it pays to look beyond the life, load, speed relationship and study the relative *installation*, *sealing*, *retainment*, *assembly* and *maintenance* requirements of each individual bearing application.

If you would like to review some of your bearing applications in order to gain an overall production or performance advantage for your product, why not pick up your telephone and call your nearest HYATT Sales Office. For your convenience, telephone numbers are listed below—and the best roller bearing application engineers in the business are at the other end of your line.

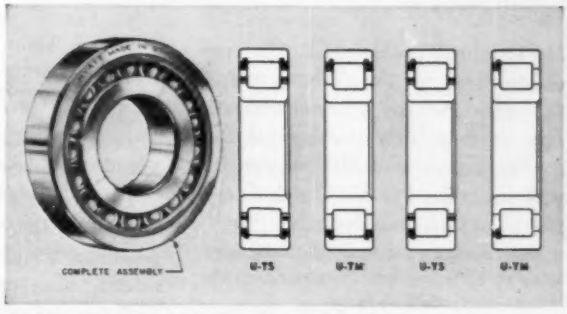
HARRISON, N. J. HUmboldt 4-4000
CHICAGO HArrison 7-8277
PITTSBURGH ATlantic 1-2927
DETROIT TRinity 2-4600
OAKLAND, CALIF. TWin Oaks 3-5362



D. Perspective and diagrams of separable inner race types



E. Perspective and diagrams of separable outer race types



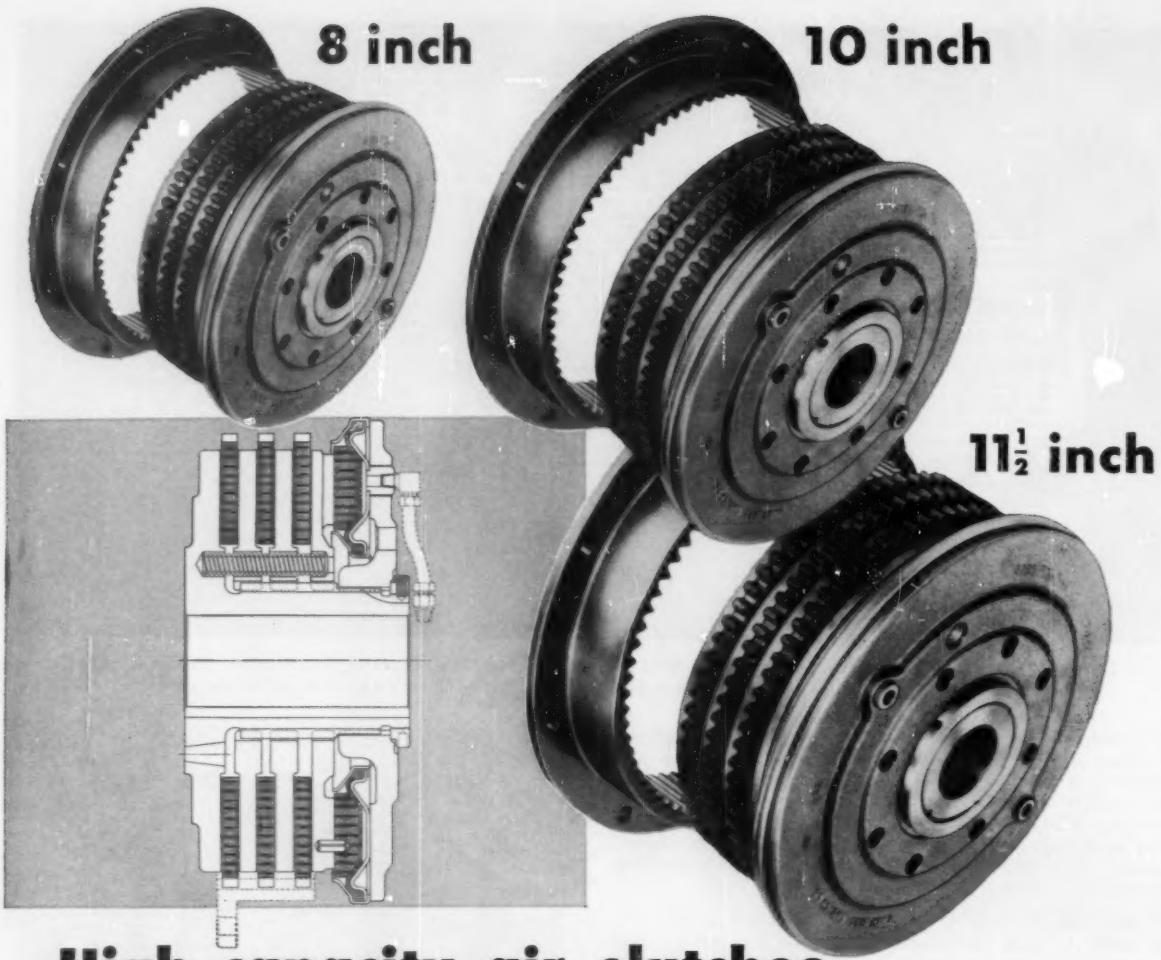
F. Perspective and diagrams of non-separable types

HYATT BEARINGS DIVISION,
GENERAL MOTORS CORPORATION,
HARRISON, NEW JERSEY

THE RECOGNIZED LEADER IN CYLINDRICAL BEARINGS

GM FORWARD FROM FIFTY

HYATT HY-ROLL BEARINGS
FOR MODERN INDUSTRY



High capacity air clutches ... up to 40% less in cost

Having clutch problems? ... Then try the new low-cost Twin Disc 8, 10 and 11½-inch PO Air Clutches. You'll find in these new clutches all the quality and dependability associated with the entire PO Air Clutch line—*plus these important benefits:*

- **New design permits highest capacity at up to 40% less cost than comparable remote-controlled units.**
- **Torque capacities to 3480 lb.-ft.**
- **Available in triple-plate, double-plate and single-plate construction.**
- **Exclusive cartridge-type reinforced neoprene diaphragm eliminates leakage ... provides longest life.**
- **Constant torque capacity without adjustment ... self-compensating for wear.**
- **Narrow width permits replacement of old-style drum or band clutches ... without extensive modification or redesigning.**
- **Suitable for air systems up to 130 pounds per square inch.**

These new PO Air Clutches are adaptable wherever the convenience of remote air control is desired. They already have proved themselves in such heavy-duty applications as rock crushers, tractor winches, pipe-extruding machines, drilling rigs, machine tools, pug mills and other industrial equipment.

Addition of the new clutches extends the Twin Disc PO Air Clutch line from 8 to 36 inches in diameter ... to 127,100 lb.-ft. in torque capacity. There's a PO Clutch for virtually every application requiring convenient remote control for connecting and disconnecting power. Write Twin Disc Clutch Company, Racine, Wis., for complete details.

TWIN DISC

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Friction Clutches and Fluid Drives

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Circle 466 on Page 19

MACHINE DESIGN

January 9, 1958

Rough Seas Ahead?

THE engineering organization in 1958 is going to have to be a trim ship—sensitive to the helm, responsive to light winds, yet steady in a gale.

Some economists are already sending up storm warnings about the future economy. Unemployment has increased—as engineers in a few industries already know. Just how bad the weather will be, or how long the seas will be rough, no one really knows.

If the stormy weather forecasts prove to be true, or even partly true, pressure will be great on both engineers and their managements—on engineers for higher production without any loss in quality, and on engineering managers for a tight organization that operates well without the lubrication of extra dollars.

All factors in engineering management will be re-examined—planning and administration, number of engineers and their abilities, hiring and training programs, and many more. Individual engineers may find themselves in the strong, white light of a management evaluation.

Perhaps the time for re-appraisal is right now—as suggested by a new series of articles on "Organizing for Productivity" starting on Page 22. If stormy weather lies ahead, the engineering organization must be seaworthy so it won't founder in heavy seas. And even if the economic forecasters prove to be wrong (as weather forecasters often are), the self-examination can help to redefine aims, objectives and methods in the engineering organization.

After all, every ship needs an occasional trip to the dry dock to have the barnacles scraped off and the seams calked!

Robert L. Stedfeld

ASSOCIATE MANAGING EDITOR

How to be a better boss

Solving the human equation in

Engineering-Group Management

By C. R. MINER
Manager, Monochrome TV Product Engineering
General Electric Co., Syracuse, N. Y.

SKILL normally follows practice where theory is applied to real situations. It is such blending of theoretical principle and practical understanding that marks the professional practitioner in any field. Opinion differs as to whether engineering management—considered apart from the broad aspects of general management—should be considered a true "profession." Semantics are ignored here, and engineering management is considered to embody these professional attributes:

1. A specialized body of knowledge.
2. Special skill in application of that knowledge.
3. A code of ethics.

There is little argument that the first of these factors—the fundamental principles of management—can be taught and learned. Company-sponsored courses and the many excellent books on the subject provide training and self-help to the qualified student.

Management principles can be taught

Skill in application of theoretical principles is another matter. Like the new engineering graduate, the management student has usually had little experience in applying his theoretical knowledge. In the case of the novice engineer, the company generally recognizes the gap between theory and practice and is tolerant of the time required for training. The new manager may find that his mistakes are viewed with more impatience. In this article, it is assumed that the theoretical aspects of engineering management have been mastered, and attention is directed instead toward developing skill in application.

Success in management depends heavily on practical understanding. When theory and practice are divorced, two results can be feared: First is the danger that young students of management will emerge from their training with idealized and often unrealistic notions of the general applicability of the new philosophies. Since the student has undoubtedly been exposed to heavy doses of modern management theory, he is likely to become bewildered for lack of a better linkage with life's realities. Perhaps the worst example of this kind of manager is one who becomes a walking fountain of strange and lofty phrases which, to him, seem to cover every situation. His subordinates are often heard to comment: "So help us, our boy has read a book."

Dust managers need horse sense!

The second possible result of separation of theory and practice is that older, experienced managers will instinctively reject valuable principles because they appear not to fit in with experience and are therefore judged as unworkable.

What's Wrong with Intuition?

Writers on professional management have labeled the unprofessional type as an "intuitive" manager. Doubtless, this is as good a term as could be used to make it apparent that professional training for the job is lacking. It would be regret-

table, however, if it were concluded that there is something basically wrong with intuition. Webster defines intuition as:

> The power of knowing, without recourse to reasoning; innate or instinctive knowledge; familiarly, a quick or ready apprehension.

Certainly, quick and ready apprehension is a necessary and desirable virtue. True skill is the result of long practice, and practice effects a transfer of mental control from the conscious to the subconscious mind. The perfect example of this transference is in learning to play a musical instrument or to drive an automobile. When a full measure of skill is attained, then subconscious control, or what is called intuitive action, replaces conscious control. In other words, the higher the skill, the more intuitive the action. Since skilled management is obviously in demand, intuitive action should not be universally condemned.

Intuition alone isn't enough

It seems that the real shortcoming of the so-called "intuitive" manager is his heavy dependence on intuition in all situations, both new and old, simple and complex, without conscious understanding of the basic principles involved. He is unable to determine when his intuition should not be trusted. For lack of theoretical knowledge, he relies wholly upon intuition; therefore, occasionally, he unconsciously violates fundamental principles, just as he frequently unconsciously applies them. He also is handicapped in his inability to explain to subordinates the reasons for his decisions and therefore comes to be regarded as arbitrary.

New management teachings speak of persuasion replacing command, and of motivation by objectives rather than by drives. The underlying logic of such techniques in human relations has always been true, being derived from basic human nature. A large measure of understanding and common sense is required of the management student if he is to understand fully and put into proper perspective the writings on modern management.

Sound decisions spring from basic knowledge

When the student moves into a position where he is required to practice good management, he encounters countless situations and problems not specifically covered by the book. Of necessity, the theoretical treatment of management is full of generalized principles which are of value as guides to solution of specific problems. However, the manner in which everyday problems frequently arise camouflages the basic principles involved. Real managerial skill exists only if the manager readily recognizes the basic truths involved when there is no "sheet music" to read, and he has to "play by ear." It is not enough to acquire knowledge. There must be understanding of the knowledge, coupled with ultimate skill in its application.

Acquiring Perspective

One of the first requirements of the engineering manager is that he develop the right perspective, meaning a broad and realistic appreciation of the role that his function plays and the nature of its contribution to the business enterprise. Of necessity, engineering must accept some subordination of certain professional ideals in deference to goals of business. This is not to say, however, that these ideals are to be forsaken. Rather, it is necessary that a proper balance be established between them and overall demands of the business.

Balance engineering and business demands

Consider the exercise of the engineer's ideal to serve society. This is a rewarding and valuable tenet of the profession, and its pursuit does much to maintain high standards of professional performance and integrity. From the purely professional viewpoint, for instance, the corporation may be regarded by the engineer as simply an instrument through which he serves society. When this concept is followed to the exclusion of other necessities of the business, such as the minimizing of costs, control of investment, timeliness of product introduction, or emphasis on sales features and styling, the business usually suffers. The engineer may then lose his chosen instrument entirely.

Proper perspective, then, must be understood and maintained by the engineering manager if the business is to succeed. There are many examples of business mediocrity due to one function or another having dominated the business to an extreme. Frankensteins are as likely to emerge from marketing, manufacturing, or accounting, as from engineering. The engineering manager is most success-

ful who skillfully integrates his function effectively into the overall effort.

Outward Relationships

The engineering manager has a particularly exacting problem in his relationships vertically and horizontally within the business organization. To a large degree, his total effectiveness is determined by his skill in handling such upward and outward relationships. Internally, the engineering manager must maintain a highly aggressive, achievement-minded attitude among his engineers to serve the ends of his function efficiently and professionally. If he has been successful in this effort, each of his professionals has a more or less built-in sense of urgency and dedication to achieve. This is a priceless possession to any functional manager.

Unfortunately, however, there are countless obstacles to the preservation of such a happy state, many of which originate in the external relationship area. There is almost always, for instance, a language barrier to complete mutual understanding between the engineering function and other corporate activities. To most marketing managers, for example, the engineer is obscured by a gobbledygook of technical language and is frequently regarded as unapproachable on equal terms. Top management, if it is not of engineering origin, may also feel this barrier. The engineering manager, therefore, must master the skill of translation of the technical into easily understood yet meaningful language.

Another important aspect in the area of external relationships is in the evolution and scheduling of the product. Classically, in a competitive product business, time left for design is the time between formulation of what the product shall be and the time when tools and material must be procured to start manufacturing on a date desired by marketing. The former is always too late and the latter is always too early. The difference, or time for design, is too little or even negative in some cases.

It does no real good to bemoan this unfortunate situation, and the alert engineering manager skillfully anticipates this possible squeeze. If he does not, the opportunity for engineering contribution is lost, and the morale of his engineers is likely to be dulled if not destroyed. Several devices are available to the manager:

1. He can alert marketing and top management to the consequences of late decisions, keeping before them at all times the schedule required of them if design time is not to be sacrificed.

2. He can gain extra engineering time by working closely with procurement, so that needlessly early releases are avoided and the procurement cycle is shortened as much as possible.

3. The engineering manager should be so attuned to commercial requirements and viewpoints that he can at all times keep his engineers productively engaged in product development which anticipates market requirements. It frequently happens, when this is done, that a very successful product results which never would have occured had the engineering manager passively waited for the commercial decision.

It is exceedingly demoralizing to an engineering group if its sense of direction is allowed to become confused. The engineering manager must use every legitimate avenue to prevent outside influences from obstructing or confusing the creative course of his group. The real danger in this lies, of course, in the tendency toward an isolated existence wherein engineering carries on for its own sake, rather than serving the needs of the business. It behooves the engineering manager to see to it that his internal programs are adequately coupled to the objectives and philosophies of the business, even when the orderly functioning of the organization designed to provide this guidance breaks down. How skillfully this is done determines to a large degree the effectiveness of the group contribution, as well as being a measure of his own promotability.

Inside Relationships

Textbooks on management and supervision cover quite adequately the mechanics of organization, delegation, performance measurement, etc. There are a few aspects, however, which are especially important in sharpening the skill of successful management of subordinates. The first of these has to do with organization and assignment. The theoretical approach is to break down the overall task into easily handled components, and then to fill the jobs thus

created with the proper kinds of people. This approach, if blindly pursued, seldom guarantees achievement. In fact, it can guarantee failure. It is not usually possible to immediately set up the ideal organization, and then obtain results with the available assortment of talents.

In his approach to the organization structure, the manager should break down the technical task so that the combination of talents and skills in all his men will be fully utilized, thereby guaranteeing maximum overall achievement. To this extent, his organization must be tailored to fit the men available. If this organization is short of the ideal, he should have a parallel program to secure the proper combination of abilities to fit the right organization in the future.

So far as possible every assignment should be a package in itself. This is not always possible, of course, but the men who are called upon to play a contributing role should at least, in future assignments, be given a well defined piece of the project to call their own. The inner urge to achieve and to be recognized must be served. There is a middle-ground between a completely subordinated service function on the one hand and an overexalted desk-admiral job on the other. The group will be stronger and happier if assignments are avoided which approach either extreme.

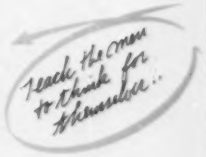
What Price Ambition?

A most important consideration in the establishment of internal relationship is the basic character of the man who is manager. Integrity is obviously a necessary prerequisite. But personal sincerity in subordinate relationships is also important. Frequently, the engineering manager must decide between two courses of action: One serves his personal ambition at the expense of his men; the other damages his personal prestige, but serves the interest and loyalty of the group. The latter is a bitter pill to swallow, particularly for the young and ambitious, but it must be swallowed.

Because he is their representative to top management, the group will not tolerate his selling them short, and the engineering manager should prize highly the respect of his men. There must always be quick and willing response to leadership. One of the surest ways to destroy such response is to show insincerity in the interest of personal ambition.

The Expendable Boss

One of the most important jobs of the engineering manager is that of the teacher. Because of his knowledge and experience, he can supply foresight to the execution of the task which frequently no other member of the group can provide. His approach, however, should be ideally limited to explaining and emphasizing the pitfalls of the situation so as to equip his engineers with the understanding required to go it alone. Only in rare instances is it wise for the manager to think out and plan a project entirely by himself. This procedure may achieve immediate results, but it does not educate the group to think and plan for itself. The functional manager should work toward his own expendability through teaching. It is only in this way that his group can become strong and progressive and that his own strengths can achieve maximum effectiveness.



This is a difficult lesson for many engineering managers to learn. Frequently, the manager, having been a successful engineer in his own right, cannot effect the change from designing to teaching and managing without great personal frustration. This transition must be accomplished, however, even at the temporary expense of efficiency, or even of excellence in design. He must regard the product as the fruit of the efforts of the group, and the group as the fruit of his own efforts. The real test of the effectiveness of the manager's skill lies in how well the group has learned to carry on without close supervision.

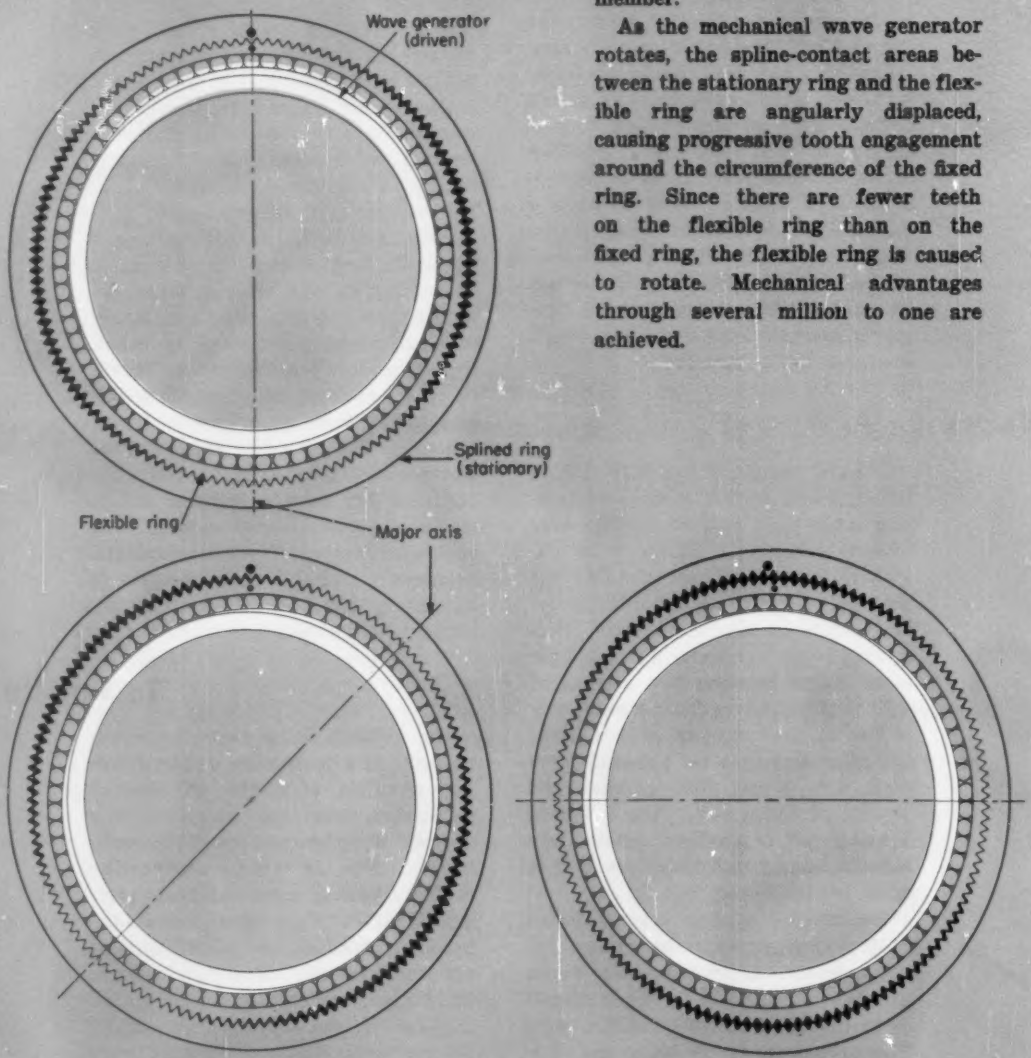
To Sum Up...

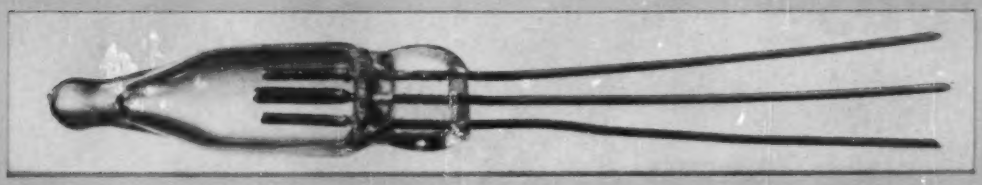
By looking at engineering management as a profession, and by drawing parallels with the engineering profession, one can reach a new plateau of understanding of the problem. Just as the engineering student, having mastered basic principles, grows into a true professional by understanding and skill, so must the management student acquire basic knowledge, understand its practical application, and achieve high skill in its use before he qualifies as a truly professional manager.

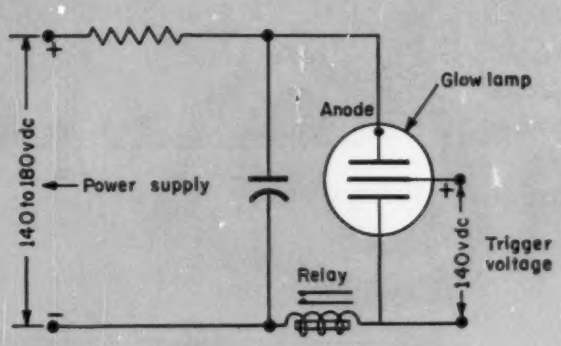
scanning the field for *ideas*

Harmonic drive principle offers a new approach to mechanical transmission of motion through controlled deflection. The unique drive, developed by the Atomic Power Dept. of United Shoe Machinery Corp., consists essentially of three parts: a fixed, internally splined ring; a mating, flexible, externally splined ring; and an elliptical wave generator. The flexible splined ring is the driven member and the elliptical wave generator is the driving member.

As the mechanical wave generator rotates, the spline-contact areas between the stationary ring and the flexible ring are angularly displaced, causing progressive tooth engagement around the circumference of the fixed ring. Since there are fewer teeth on the flexible ring than on the fixed ring, the flexible ring is caused to rotate. Mechanical advantages through several million to one are achieved.

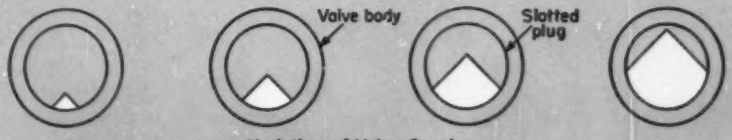




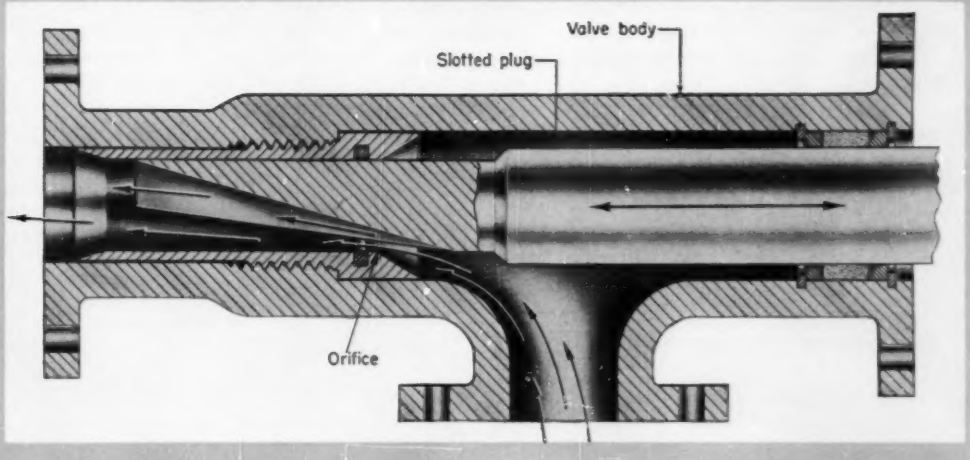


Simplified switching control of electronic circuits is accomplished by an unusual cold-cathode glow-lamp design incorporating three electrodes. Developed by General Electric, the lamp provides circuit switching for voltages applied across the two outer electrodes. After application of sufficient triggering voltage to the center electrode to start the lamp, current flows between the outer electrodes and through any devices in the power circuit. Once started, the lamp will continue to carry current until the circuit is interrupted or a reverse current applied.

Tapered-vee orifice design eliminates clogging and provides accurate flow control of gasses, liquids, and slurries in needle-valve applications. In a design developed by General-American Valve Co., flow through a circular opening is controlled by a tapered vee-slot in a movable plug. Clogging is prevented by concentrating all of the flow area in one triangular section instead of around an annular ring.

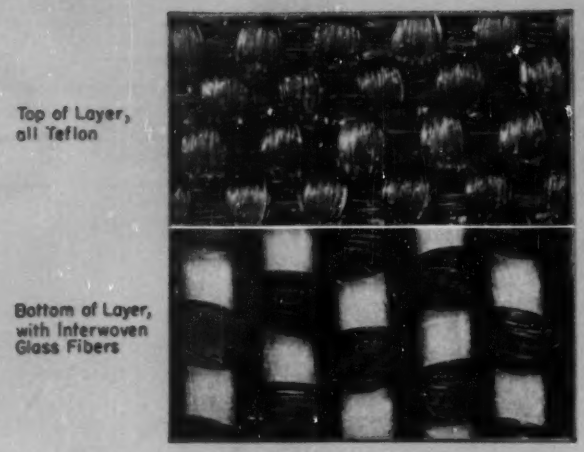


Variation of Valve Opening

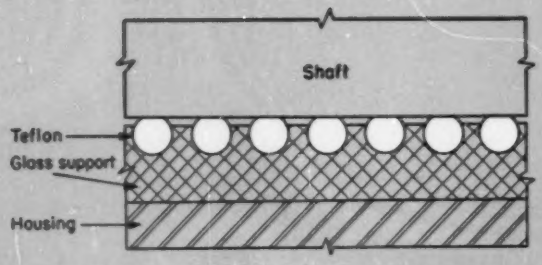


ideas

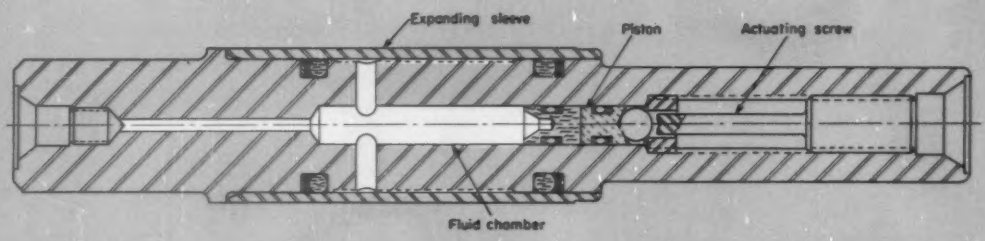
Glass-and-Teflon surface combines high load-bearing properties with self-lubricating characteristics for rubbing-contact applications. The outer face of the material is a weave of Teflon fibers interwoven on the back with glass fibers. Back-up layer is a glass-fiber weave impregnated with Phenolic. The two layers are bonded and cured at elevated pressure and temperature, producing a Teflon-weave face for self lubrication interlocked with the glass-Phenolic supporting structure for load-bearing capacity. Under load, the Teflon fibers, which are completely surrounded by supporting material, can not flatten or extrude. The material was developed by Micro-Precision Div. of Micromatic Hone Corp. for use in high-capacity spherical bearings.



Surface Layer Before Bonding



Positive hydraulic locking of shaft assemblies is accomplished by an expanding shaft-sleeve construction that assures concentricity between shaft and mating part. In an expanding arbor designed by A and C Engineering Co. Inc., hydraulic pressure is used to expand a steel sleeve to engage and hold mounted parts. The hydraulic system is sealed within the arbor, without exterior connections. Pressure is applied to the fluid by an actuating screw that forces a piston against the fluid.



Some fundamental principles of

PATENT ETHICS

A patent owner enjoys a monopoly well-protected by law. However, protection against patent infringement may be refused by the courts if the patent owner obtains or uses this monopoly in an unethical manner. The principle of "clean hands" is illustrated by this discussion of representative court decisions.

By ALBERT WOODRUFF GRAY
Forest Hills, N. Y.

BORN possibly of Biblical characterization, the ancient legal doctrine that he who comes into a court of equity must come with "clean hands" has assumed increasing importance in patent litigation. In particular, this principle has been applied in court actions where patent owners have attempted to protect their patents against infringement. The ancient precept clearly defines certain rules of conduct, or ethics, that patent owners must abide by.

A TYPICAL case occurred several years ago in litigation involving patents for a ditching machine. Apprehensive that the prior use of this machine might be disastrous to claims for its validity as a patent, an officer of the patent-owning company sought out a witness to this prior use and not only purchased his silence but secured his affidavit that any prior use was an abandoned experiment.

Subsequently, the patent-owing company became involved in two court actions to protect its patents against infringement. In the first action it was successful, no mention being made of the prior arrangement with the witness. During the conduct of the second case, however, the witness disregarded his purchased silence and the case eventually reached the United States Supreme Court. Here, the suit was dismissed, with the court saying, "It is one of the fundamental principles upon which equity jurisprudence is founded that before a complainant can have a standing in court he must first show that he has a good and meritorious cause of action and he must come into court with clean hands. He must be frank and fair with the court. Nothing about the case under consideration should be guarded but everything that tends to a full and fair determination of the matters in controversy should be placed before the court."

To this the court added a quotation from a leading authority: "The governing principle is that whenever a party who, as actor, seeks to set the judicial machinery in motion and obtain some remedy, has violated conscience or good faith, or other equitable principle, in his prior conduct, then the doors of the court will be shut against him. The court will refuse to interfere on his behalf, to acknowledge his right or to award him remedy.

"It is a principle in chancery that he who asks relief must have acted in good faith. The equitable powers of this court can never be exerted in behalf of one who has acted fraudulently or who by deceit or any unfair means, has gained an advantage."

Application of this rule, however, is restricted to conduct or acts directly related to the circumstances before the court, not to those occurring independently of the transaction in controversy.

"But courts of equity do not make the quality of suitors the test," asserted that court of this

doctrine. "They do not close their doors because of misconduct, whatever its character, that has no relation to anything involved in the suit, but only for such violation of conscience as in some measure affects the equitable relations between the parties in respect of something brought before the court for adjudication. They apply the maxim not by way of punishment for extraneous transgressions but upon considerations that make for the advancement of right and justice."[1]

IN a similar appeal before a federal court many years ago, involving the denial of relief to parties deemed by the court to be guilty of sharp and unconscionable practices, a comment was made by the court that has become a classic in its characterization of this doctrine.

"A suit in equity is an appeal for relief to the moral sense of the chancellor. A court of equity is a form of conscience. Nothing but good faith, the obligations of duty, and reasonable diligence will move it to action. Its decree is the exercise of discretion—not of arbitrary and fickle will, but of a wise judicial discretion controlled and guided by the established rules and principles of equity jurisprudence.

"One of the most salutary of these principles is expressed by the maxims, 'He who comes into a court of equity must come with clean hands,' and 'He who does inequity cannot have equity.'

"A court of equity will leave to his remedy at law—will refuse to grant relief to—one who in the matter of transaction concerning which he seeks aid, has been wanting in good faith, honesty or righteous dealing. While in a proper case it acts upon the conscience of a party to compel him to do that which is just and right, it repels from its precincts remediless the party who has been guilty of bad faith, fraud or any unconscionable act in the transaction which forms the basis of his suit."[2]

In the foregoing case the court repeated in substance the principle made by an English court in refusing protection to a trademark owner who had employed his mark for deception and fraud. There it had been said:

"When the owner of a trademark applies for an injunction to restrain another from injuring his property by making false representations to the public, it is essential that the trademark owner should not in his trademark or in the business connected with it, be himself guilty of any false or misleading representation; for if the trademark owner makes any false statement in connection with the property he seeks to protect, he loses, and very justly, his right to claim any assistance in a court of equity."[3]

WHILE in the past this doctrine under which courts refuse their aid to litigants who themselves have been lacking in clean hands, has been applied to widely different circumstances, it is noteworthy in its application to infringement suits by owners of patents whose hands have been soiled in the conduct of monopolistic practices.

In a New York court several years ago suit was brought by an electrical manufacturer against a competitor for infringement of certain fluorescent lamp patents. The government attempted to become a party to the action in support of the defense. Under a licensing agreement, alleged by the government to have been made with another manufacturer of electrical equipment, the patent-owning company had maintained a system of distribution of fluorescent lamps through more than 100,000 agents, and by this system the prices of lamps sold by these companies to distributors, and thence to the consuming public remained identical. Because of these acts, the government asserted, "The patent owner comes into court with unclean hands, having exploited its patents in a fashion contrary to the antitrust laws and public policy and that therefore this court should withhold its assistance from such a use of the patent by declining to entertain a suit for infringement."[4]

While the court declined to allow the government to intervene in the suit—it concurred with the government's opinion. The patent owner was debarred from prohibiting the infringement since the patent had been misused.

THE principle of clean hands, in its role of defense to infringement actions, was recently summarized by the United States Supreme Court in a decision that at present is the authority for disposition of controversies of this character. Suit had been brought by a salt manufacturer for the infringement of a patented salt dispenser.

The defense contended that these patented dispensers were licensed with the stipulation that they would be used only in dispensing the products of the patent owner. Sustaining the dismissal of the infringement action the Supreme Court made this summary: "Where the patent is used as a means of restraining competition with the patentee's sale of an unpatented product, the successful prosecution of an infringement suit even against one who is not a competitor in such a sale is a powerful aid to the maintenance of the attempted monopoly of the unpatented article and is thus a contributing factor in thwarting the public policy underlying the granting of the patent.

Equity may rightly withhould its assistance from such a use of the patent by declining to entertain a suit for infringement and should do so at least until it is made to appear that the improper practice has been abandoned and that the consequences of the misuse of the patent have been dissipated."[5]

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1. Keyston Driller Co. v. General Excavtor Co., 296 *U. S.* 240, Ohio, December 4, 1933.
2. Michigan Pipe Co. v. Fremont Ditch, Pipe Line & Reservoir Co., 111 Fed. 284, Col., October 7, 1901.
3. Leather Cloth Co. v. American Leather Cloth Co., 4 De G. J. & S. 137.
4. General Electric Co. v. Hygrade Sylvania Corp., 45 *F. S.* 714 New York, May 29, 1942
5. Morton Salt Co. v. G. S. Suppiger Co., 314 *U. S.* 488, January 5, 1942.

How to design for

FORM ROLLING

of knurls, splines, and serrations

Cold forming by rolling can produce many non-thread forms. This article, second in a group of three covering design and specification of thread and form-rolled parts, tells how to design to take maximum advantage of this fast, economical production process.

KNURLING is commonly used for decorative purposes, for surfaces where component parts are locked or keyed together in unit assemblies, and where manual gripping is necessary. Knurling is produced by displacement of material when the knurl tool is pressed against surface of a rotating work blank. Most commonly used knurls are straight, diagonal, and diamond patterns, Fig. 1. Special knurls may be used to produce teeth on tapered, convex or concave surfaces.

Diamond knurling may have either a male or female pattern. Male diamond knurls have raised points and produce a female impression; female diamond knurls have depressed points and produce a male impression. Male diamond-pattern knurling, with raised points on the work, is most commonly used since it can easily be produced.

A knurled tooth is V-shaped with tooth depth less than depth of a theoretical V-form because the tooth has a rounded root and crest. Relationship between actual tooth depth and theoretical V varies with pitch of the teeth. On finer pitches,

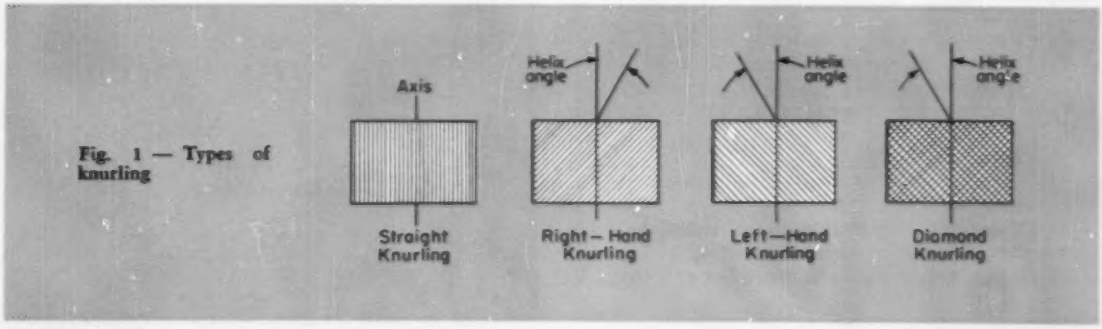


Fig. 1 — Types of knurling

Table 1—Circular Pitches for Knurling

Straight Knurling		Diagonal and Diamond Knurling (30-deg helix angle)			
		Teeth per Inch		Circular Pitch	
Teeth per Inch	Circular Pitch (in.)	Normal	Transverse	Normal (in.)	Transverse (in.)
12	0.0833	12	10.39	0.0833	0.0962
16	0.0625	16	13.86	0.0625	0.0722
19	0.0526	19	16.45	0.0526	0.0607
20	0.0500	20	17.32	0.0500	0.0577
24	0.0417	24	20.78	0.0417	0.0482
25	0.0400	25	21.65	0.0400	0.0462
29	0.0345	29	25.11	0.0345	0.0398
30	0.0333	30	25.98	0.0333	0.0385
35	0.0286	35	30.31	0.0286	0.0330
40	0.0250	40	34.64	0.0250	0.0289
41	0.0244	41	35.51	0.0244	0.0282
47	0.0213	47	40.70	0.0213	0.0246
50	0.0200	50	43.30	0.0200	0.0231
80	0.0125	80	69.28	0.0125	0.0144

the tooth is a smaller proportion of the theoretical V-depth than on coarser pitches. Female diamond patterns have shallower tooth depth than male diamond patterns. Tooth form is shown in Fig. 2.

Two general types of knurling are now in use—circular pitch and diametral pitch. Circular pitch system, which is older and has been in use many years, is based on circular-pitch and teeth-per-inch formulas related to circumference of the work. Diametral-pitch system is covered by American Standard B5.30-1953 in which 64, 96, 128, and 160 diametral pitches are used for work diameters ranging from 3/32 through 1 in. Purpose of diametral-pitch knurling is to permit work-blank diameters of standard fractional stock sizes to be used.

Circular-Pitch Knurling: Related to distance between teeth on circumference of work blank, circular-pitch knurling is usually expressed in terms of number of teeth per inch, tpi, although sometimes erroneously referred to as pitch. When knurling is used for decorative appearance purposes or for a hand grip, it is only necessary to specify approximate teeth per inch required, thereby permitting standard knurls to be used.

Tooth pattern of knurling should always be specified, stating whether it is straight, diagonal or diamond pattern; if diagonal knurling, whether right or left hand; if diamond, whether male or female; and the angle of helix in both latter cases.

Knurl Nomenclature

- D_k = Outside diameter of knurling tool
- D_w = Theoretical or approximate diameter of blank
- N_k = Number of teeth on knurling tool
- N_w = Number of teeth on work
- P = Diametral pitch
- p = Circular pitch on blank diam for straight knurling
- p = Transverse circular pitch on blank diam for diagonal or diamond knurling
- a = Angle between axes of knurl tool and work

Knurling is occasionally referred to as coarse, medium, or fine. Where no reference is made to diameters, 16 to 20 tpi is sometimes referred to as coarse, 25 to 35 as medium, and 40 to 80 as fine. Much confusion has resulted from this practice because diameter of knurl, in many instances, influences selection of knurl pitch used. What appears to be a coarse pitch on a small diameter may seem like medium or fine on a larger diameter.

Although teeth per inch is measured on circumference of the work-blank diameter, the approximate tpi may be measured on outside diameter of knurling for reference purposes. For convenience in measuring approximate tpi, tooth pattern of the knurling may be quickly transferred to a sheet of paper. This is done by placing a piece of carbon paper (carbon side down) on a sheet of paper, on a flat surface, and rolling the knurled surface on the carbon paper. Impressions of the knurl pattern will be transferred to the paper for approximate measurements.

In deciding knurled pattern for a part, it is first necessary to determine whether straight, diagonal or diamond knurling is desired and then how many teeth per inch is best suited for the application. For general-purpose knurling, only limited

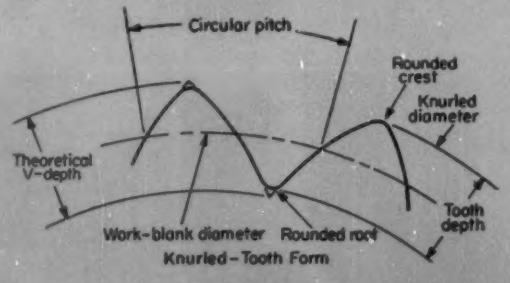


Fig. 2—Knurl-tooth form, with definitions of knurling terms

dimensions are necessary. Any reference to tooth or space angles is omitted.

Table 1 is for visualizing corresponding circular pitches for different number of teeth per inch. Relationship between normal and transverse circular pitches is illustrated in Fig. 3. Knurled diameters and circular pitch of knurl are related. Circumference of work blank should be an approximate multiple of the circular pitch for straight knurling and transverse circular pitch for diagonal and diamond knurling. Blank diameters vary with circular pitch of knurling selected.

In general practice, depth of tooth provided with standard circular-pitch knurls approximates the following percentages of circular pitch:

Straight teeth—35 per cent circular pitch
Diagonal teeth—35 per cent normal circular pitch
Diamond pattern, male—40 per cent normal circular pitch
Diamond pattern, female—25 per cent normal circular pitch

Approximate increase in blank diameters for different numbers of teeth per inch with straight, diagonal and diamond pattern knurling given in Table 2, are based on knurling soft steels and may vary slightly with different materials.

Care should be exercised not to specify knurled diameters with too few teeth and consideration should be given to length of knurling and pressure required to force knurl into the work. Greatest pressures are exerted by coarse pitches and wide knurls. Table 3 may be used as a guide in selecting smallest knurled diameters for knurling with different numbers of teeth per inch and widths of knurl faces.

For good quality, general purpose knurling, limits and tolerances of knurled diameters are relatively unimportant and are not specified. However, where necessary to specify tolerances and limits on knurled diameters, tolerances may be expressed as 30 to 50 per cent of circular pitch, with about 75 per cent of the tolerance in a minus direction. Use as liberal a tolerance as possible, for low manufacturing cost. For precision straight knurling where component parts are to fit together, tolerances may be reduced to approximately 15 to 20 per cent of circular pitch of knurling, in the minus direction.

DIMENSIONING CIRCULAR-PITCH KNURLING: Uniform dimensioning should include length and diameter of knurling and specifications of teeth, Fig. 4. Method of dimensioning diameters and tooth specifications is important, since improper use of dimensions may result in considerable confusion.

The designer should always allow leeway in dimensioning knurled diameters so that manufacturing departments may experiment to establish exact relationship between work-blank diameter and diameters on finished product. Approximate amount to add to blank diameter to obtain knurled diameters for different numbers of teeth per inch and types of knurling is given in Table 2.

Allowance for variation in number of teeth in knurled diameter should also be made unless use of knurled surface demands an exact number of teeth. In such cases, precise limits on blank diameters will be required and can only be determined by experimentation for specific material and work to be knurled.

Diametral-Pitch Knurling: American Standard B5.30-1953 has been designed on basis of diametral pitch and developed for work-blank diameters of standard fractional stock sizes in multiples of 1/64 or 1/32 in., depending upon diametral pitch se-

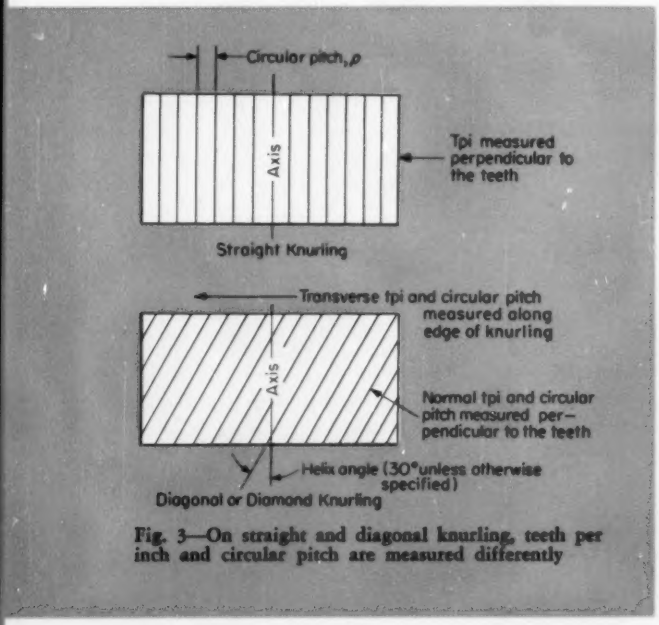

Circular pitch, p
Axis
Tpi measured perpendicular to the teeth
Straight Knurling
Transverse tpi and circular pitch measured along edge of knurling
Axis
Normal tpi and circular pitch measured perpendicular to the teeth
Helix angle (30° unless otherwise specified)
Diagonal or Diamond Knurling

Fig. 3—On straight and diagonal knurling, teeth per inch and circular pitch are measured differently

Table 2—Increase of Blank Diameter from Knurling

Teeth per Inch*	Straight and Diagonal† Knurling (in.)	Diamond Knurling† Male (raised points) (in.)	Diamond Knurling† Female (depressed points) (in.)
12	0.029	0.028	....
16	0.022	....	....
20	0.018	0.020	0.012
25	0.014	0.016	0.010
30	0.012	0.013	0.008
35	0.010	....	....
40	0.009	0.010	....
50	0.007	0.008	0.005
80	0.004	0.005	....

All values based upon knurling of soft steel.
*Normal tpi on diagonal and diamond knurling.
†Helix angle of 30 deg.

Table 3—Minimum Knurled Diameters

Teeth per Inch*	Roll Width: 3/16-in.	Minimum Blank Diameters (in.) 1/4-in.	3/8-in.
16	....	13/32	1/2
20	5/16	11/32	7/16
25	1/4	9/32	3/8
30	7/32	1/4	5/16
35	3/16	7/32	9/32
40	5/32	3/16	1/4
50	1/8	5/32	7/32
80	5/64	7/64	11/64

*Normal tpi for diagonal knurling.

lected. Fractional blank-diameter sizes apply to straight and diagonal knurling for both in-feed and end-feed knurling.

Four standard diametral pitches available are 64, 96, 128, and 160. The 96 and 160 diametral pitches are for blank diameters in fractional increments of 1/32 in. and the 64 and 128 diametral pitches are for blank diameters in fractional increments of 1/64 in. The American Standard recommends that use of 64 pitch be avoided as much as possible. For simplification of tools, preference is given to 96 pitch.

Diametral pitch and number of teeth are always measured in a transverse plane for diagonal as well as straight knurling, Fig. 3. A comparison of diametral pitches, teeth per inch, and circular pitches is shown in Table 1.

DIMENSIONING DIAMETRAL - PITCH KNURLING: Tooth pattern of knurling must be given, stating whether straight, diagonal or diamond pattern; if diagonal knurling, whether right or left hand; and the helix angle, Fig. 4.

CLASSES OF KNURLING: The American Standard B5.30-1953 for straight and diagonal knurling applies to work blank diameters up to 1 in. and includes three classes of tolerances, Table 4. These classes and recommended applications are:

Class I: Tolerances in this classification may be applied to straight, diagonal, and raised-diamond knurling where knurled outside diameter of work need not be held to close dimensional tolerances. Such applications include knurling for decorative effect, grips on thumbscrews, and inserts for moldings and castings.

Class II: Tolerances in this classification may be applied to straight knurling only and are recommended for applications requiring closer dimensional control of knurled outside diameter than Class I tolerances.

Class III: Tolerances in this classification may be applied to straight knurling only and are recommended for applications requiring closest possible dimensional control of knurled outside diameter. Such applications include knurling for close fits.

MINIMUM DIAMETERS AND NUMBER OF TEETH: Care should be taken not to specify knurled diameters with too few teeth. Smallest blank diameters and minimum number of teeth appearing in American Standard for different diametral pitches are given in Table 5.

Blanks for Knurling: Knurled diameter is larger than unknurled blank by an amount approximately equal to tooth depth of the knurl used. Blank diameters for knurling are therefore approximately equal to the knurled diameter minus tooth depth. Since a variation in blank diameter results in variation of knurled diameter, blank-diameter tolerances must be controlled, according to accuracy of knurling to be produced. Uniformity of blanks is required to produce uniform knurling.

CIRCULAR-PITCH KNURLING: Blank diameter has

Table 4—Knurled OD Tolerances

Diametral Pitch	Class I	Class II	Class III
64	+0.005 in. −0.012	+0.000 in. −0.010	+0.000 in. −0.006
96	+0.004 −0.010	+0.000 −0.009	+0.000 −0.005
128	+0.003 −0.008	+0.000 −0.008	+0.000 −0.004
160	+0.002 −0.006	+0.000 −0.006	+0.000 −0.003

Table 5—Diametral-Pitch Knurling

Diametral Pitch	64	96	128	160
Teeth per inch, approx.*	20.4	30.6	40.7	50.9
Circular pitch*	0.0491	0.0327	0.0245	0.0196
Depth of tooth or increase in knurled diameter				
Straight knurling, in.	0.024	0.016	0.012	0.009
Diagonal knurling, in.	0.021	0.014	0.010	0.008
Minimum number of teeth	24	24	18	15
Work-blank diameters				
Size range, minimum, in.	3/8	1/4	9/64	3/32
maximum, in.	1	1	1	1
Increments, in.	1/64	1/32	1/64	1/32

*On diagonal knurling, transverse tpi and transverse circular pitch.

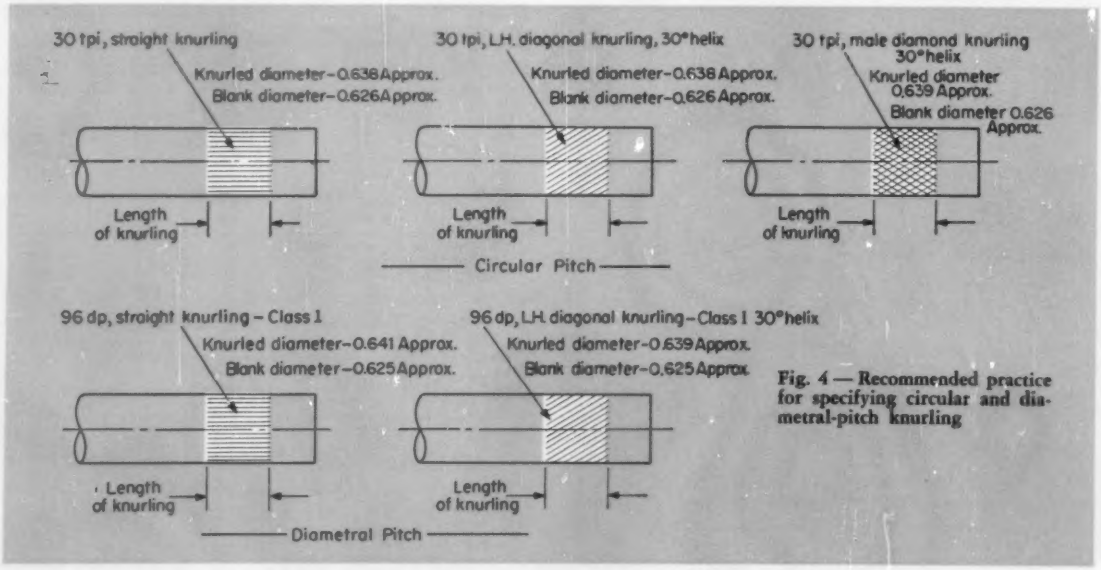


Fig. 4 — Recommended practice for specifying circular and diametral-pitch knurling

a definite relation to proper tracking of knurl on original contact with the work. Circumference of work blank should be an approximate multiple of the circular pitch of straight knurls and the transverse circular pitch of diagonal knurls. With improper blank diameters, teeth of the knurl, as they feed into the work, fail to mesh with indentations made during first revolution of the blank. Blanks for straight knurling should be free of taper and reasonably smooth.

Improper or varying blank diameters result in reduced knurl life, poor finish, double teeth, uneven tooth profile, and inability to obtain uniformity of number of teeth and knurled diameter. With these variations possible, special attention must be given to careful specification and dimensioning of blanks to make sure blank diameter is consistent with predetermined size.

Many variations enter into knurling that make it difficult to establish a formula that will accurately predetermine exact blank diameters. Following formulas may be used, however, for determining a theoretical work-blank diameter, or for obtaining circular pitch and number of teeth that may be rolled on a blank of a specified diameter for in-feed and end-feed knurling.

$$D_w = \frac{pN_w}{\pi}$$

$$N_w = \frac{\pi D_w}{p}$$

$$p = \frac{\pi D_w}{N_w}$$

Transverse circular pitch should be used when computing number of teeth on work blank with diagonal and diamond knurling. Teeth per inch may be translated into circular pitch by use of Table 1. Tolerances for work-blank diameters vary with knurling requirements. For general-purpose knurling, tolerances usually range between 5 to 8 per cent of circular pitch; for precise knurling, approximately 2 to 4 per cent of circular pitch. Allowance for variation in number of teeth in knurled diameter should be made unless use of knurled surface demands an exact number. In such cases, precise limits on blank diameters will be be required.

Example 1: Determine theoretical blank diameter for rolling 60 straight teeth on a knurled surface with a 20 tpi knurl.

$$D_w = \frac{pN_w}{\pi} = \frac{0.0500 \times 60}{3.1416} = 0.955 \text{ in.}$$

theoretical-blank diameter where $p = 0.0500$ (circular pitch for 20 tpi, Table 1).

Example 2: Determine approximate number of diagonal teeth that can be rolled on a blank 0.625 in. diam with a 30 normal-tpi knurl having a 30-deg helix angle.

$$N_w = \frac{\pi D_w}{p} = \frac{3.1416 \times 0.625}{0.0385} = 51 \text{ teeth}$$

where $p = 0.0385$ (transverse circular pitch for 30 tpi, Table 1).

A proportional formula frequently used for selecting diameter and number of teeth on a knurl to produce a specified number of teeth on a given work-blank diameter gives relationships of diameters and teeth on both knurling and the knurl. With several of these elements as variables, proportions can be quickly established on a slide rule to permit a simple solution of knurl-design problems.

$$\frac{D_w}{N_w} = \frac{D_k}{N_k}$$

Diametral-Pitch Knurling: Formula for theoretical work-blank diameters is

$$D_w = \frac{N_w}{P}$$

Tolerances for work-blank diameters vary with knurling requirements. For general-purpose knurling, tolerances usually range between 5 to 8 per cent circular pitch and for precise knurling, approximately 2 to 4 per cent of circular pitch.

End-feeding for diagonal knurling, with axes of straight knurls set over at a specified helix angle, usually requires decimal-size blank diameters. For end-feed knurling with straight-tooth knurls

$$D_w = \frac{N_w}{P \cos \alpha}$$

Number of teeth produced on work blank is measured in the transverse plane and may be determined with formula for diagonal knurling:

$$N_w = D_w P \cos \alpha$$

Example: If 30-deg diagonal knurling were to be produced on 1-in. stock with a 96-diametral pitch straight knurl (0.86603 equals cosine of 30 deg).

$$N_w = 1.000 \times 96 \times 0.86603 = 83.14 \text{ teeth}$$

Increasing angle between knurl axis and work axis to approximately 30¼ deg would provide good tracking of the knurl and make it possible to obtain an even 83 teeth instead of 83.14. By reducing diameter of work blank to a decimal size, good tracking of knurl can be obtained for 30-deg diagonal knurling:

$$D_w = \frac{N_w}{P \cos \alpha} = \frac{83}{96 \times 0.86603} = 0.998 \text{ in.}$$

▶ Splines and Serrations

Often erroneously referred to as the same, the terms "spline" and "serration" are interchanged incorrectly. There are similarities and differences between the two, and unless use is made of the proper designation, considerable misunderstanding may result.

Splines and serrations are similar in many respects. Basic tooth form for both has an involute profile and is based on diametral pitch. Major

Spline and Serration Nomenclature

b = Dedendum
D = Pitch diam
D_b = Base circle diam
D_o = Major diam
D_r = Minor diam
d = Addendum
p = Circular pitch
r = Fillet radius
t = Circular tooth thickness
β = Pressure angle

differences between splines and serrations are in pressure angles, range of pitches, range of diameters, uses and classes of fits.

Nomenclature for splines and serrations is identical and both agree as nearly as possible with standard gear nomenclature. Most commonly used terms of external, involute spline, and serration tooth nomenclature are illustrated in Figure 5. Since rolling is concerned with external surfaces only, information and tables are confined, for the most part, to specifications dealing with external splines and serrations. Basic dimensions common to both splines and serrations are pitch diameter, circular pitch, major and minor diameters, addendum and dedendum. Formulas for developing these basic dimensions are also identical. Other basic formulas are similar, but vary by factors that determine the various fits.

Splines and serrations are identified by fractional designations such as 16/32, 24/48, etc. Upper figure of designation specifies diametral pitch, as the 16 in 16/32, and is used to determine diameter and number of teeth. In the American Standard, lower figure of fractional designation is always twice the upper figure. A fraction made by placing one over the lower figure gives the addendum of tooth form as a fraction of an inch. For example, 32 in 16/32 indicates that the addendum is 1/32 in.

Pressure angles in the American Standard are 30 deg for involute splines and 45 deg for serrations. There are 15 standard diametral pitches of involute splines, ranging from ½ to 48/96. Involute serrations have 9 standard diametral pitches ranging from 10/20 to 128/256. Standard involute-spline major diameters range from approximately 0.1458 to 51.000 in.; standard involute-serration major diameters range from 0.0937 to 10.100 in., Table 6.

Splines are mostly used where axial movement is required with rotation. Three types of fits for spline members are standard, Table 7. Each type is further divided into three classes of fits:

1. Sliding fits with clearance at all points.
2. Close fits on either major diameter, sides of teeth, or minor diameter.
3. Press fits with interference on either major diameter, sides of teeth, or minor diameter.

Serrations are used more for fixed position fastening, and have three classes of fits: Class A—Loose; Class B—Close; Class C—Press. Fit is controlled by tooth thickness on pitch diameter.

Allowable Errors: For both involute splines and serrations, allowable errors include profile, spacing, lead, and out-of-roundness. Definition of each is given in following paragraphs, and limiting dimensions for each are illustrated in Fig. 6.

PROFILE ERROR: Difference between highest and lowest readings of a dial indicator, moving along the true involute curve in the plane of rotation, and having a finger contacting the active tooth profile.

ACCUMULATED PITCH ERROR (SPACING): Greatest difference in any two teeth between actual and theoretical tooth spacing on the same circle. Measurements are taken from one pitch point selected as reference, to corresponding points on all other teeth, and are affected by involute error, out-of-

Table 6—External, Involute Splines and Serrations

	Splines (30-deg pressure angle) ASA B5.15-1950		Serrations (45-deg pressure angle) ASA B5.26-1950	
	Teeth	Major Diam (in.)	Teeth	Major Diam (in.)
128/256	.....	.....	11 to 24	0.0937 to 0.1953
80/160	.....	.....	11 27	0.1500 0.3500
64/128	.....	.....	11 31	0.1875 0.5000
48/96	6 to 50	0.1458 to 1.0625	6 60	0.1459 1.2709
40/80	6 50	0.1750 1.2750	6 60	0.1750 1.5250
32/64	6 50	0.2188 1.5938	6 60	0.2188 1.9063
24/48	6 50	0.2917 2.1250	6 100	0.2917 4.2083
20/40	6 50	0.3500 2.5500	.....	.....
16/32	6 50	0.4375 3.1875	6 100	0.4375 6.3125
12/24	6 50	0.5833 4.2500	.....	.....
10/20	6 50	0.7000 5.1000	6 100	0.7000 10.1000
8/16	6 50	0.8750 6.3750	.....	.....
6/12	6 50	1.1667 8.5000	.....	.....
5/10	6 50	1.4000 10.2000	.....	.....
4/8	6 50	1.7500 12.7500	.....	.....
3/6	6 50	2.3333 17.0000	.....	.....
2½/5	6 50	2.8000 20.4000	.....	.....
1/2	6 50	7.0000 51.0000	.....	.....

Table 7—Types and Classes of Spline Fits

Type of Fit	Controlled by	Class	
Major diameter	Varying major diameter of external spline	I	Sliding
		II	Close
		III	Press
Sides of teeth	Varying tooth thickness. Normally used for fillet-root type spline.	A	Sliding
		B	Close
		C	Press
Minor diameter	Varying minor diameter of internal spline	X	Sliding
		Y	Close
		Z	Press

roundness and runout.

LEAD ERROR: Deviation of teeth from the dimensional lead. Lead error is usually measured by traversing a dial indicator along the tooth face, normal to the pitch line and parallel to axis of the spline.

OUT-OF-ROUNDNESS: Difference between maximum and minimum measurements over or between pins.

Application of Allowable Errors: Not all possible extremes will occur at one time, so instead of using total of all allowable errors, 60 per cent has been adopted in the American Standard as a proportion of total allowable errors to use for allowable-error tolerance when computing effective fits. However, greater allowable-error tolerances are sometimes used for lower manufacturing costs.

ROLLING TOLERANCE: Rolling tolerance is a specification used as a machining tolerance in the American Standard for both involute splines and serrations. It varies with diametral pitch and allowable-error tolerance and is equal to total tolerance of the fit minus allowable-error tolerance, Fig. 6. Maximum limit for rolling is affected by allowable-error tolerance. Minimum limit for rolling is same as minimum limit of size of external member.

Specifying Measurements: Tables in the Standards for over-pin measurements cover only rolling (machining) limits, and exclude consideration of errors in profile, spacing, lead, or out-of-roundness.

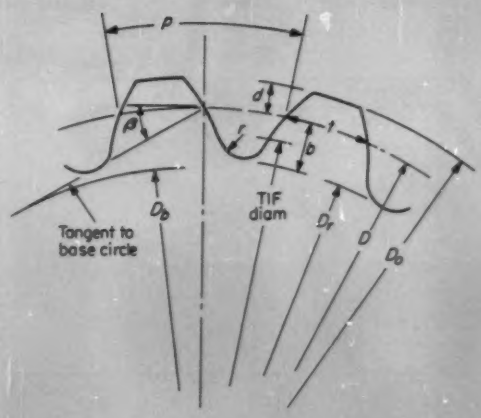


Fig. 5—Tooth form for splines and serrations

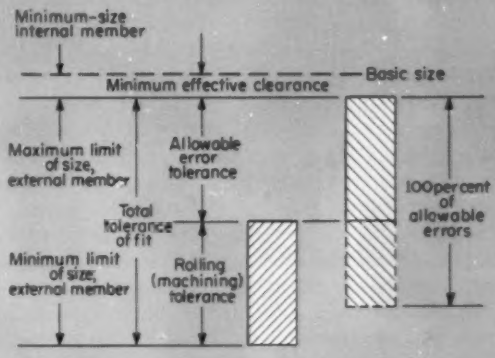

Minimum-size internal member
Basic size
Minimum effective clearance
Maximum limit of size, external member
Allowable error tolerance
100 per cent of allowable errors
Total tolerance of fit
Minimum limit of size, external member
Rolling (machining) tolerance

Fig. 6—Relationship between rolling tolerance and total of allowable errors

Table 8—Preferred Tooth-Fillet Radius

Fillet Radii for Involute Splines (In.)

Number of Teeth	Diametral Pitch 32/64	24/48	20/40	16/32	12/24	10/20
18	0.017	....	....	....	....	....
19	0.017	0.023	....	....	....	....
20 to 22	0.017	0.023	0.027	0.034	0.045	....
23 to 27	0.017	0.023	0.027	0.034	0.045	0.055
28 to 41	0.017	0.023	0.027	0.034	0.046	0.055
42	0.017	0.023	0.027	0.034	0.046	0.056
43 to 50	0.017	0.023	0.028	0.034	0.046	0.056

Fillet Radii for Involute Serrations (In.)

Number of Teeth	Diametral Pitch 48/96	40/80	32/64	24/48	16/32	10/20
18 to 20	0.010	0.012	0.015	0.019	....	....
20 to 22	0.010	0.012	0.015	0.019	0.029	....
23 to 28	0.010	0.012	0.015	0.020	0.029	0.047
29 to 60	0.010	0.012	0.015	0.020	0.029	0.047
61 to 74	....	....	....	0.020	0.029	0.047
75 to 100	....	....	....	0.020	0.030	0.047

Table 9—Minimum Number of Teeth

Diametral Pitch	Circular Pitch	Splines: Through-Feed Rolling: Minimum Number of Teeth	Splines: Through-Feed Rolling: Major Diam (in.)	In-Feed Rolling: Minimum Number of Teeth	In-Feed Rolling: Major Diam (in.)	Through-Feed Rolling: Minimum Number of Teeth	Through-Feed Rolling: Major Diam (in.)
128/256	0.0246	..	....	22	0.180	17	0.141
80/160	0.0393	..	....	22	0.288	17	0.225
64/128	0.0491	..	....	22	0.359	17	0.281
48/96	0.0654	18	0.396	23	0.500	18	0.396
40/80	0.0785	18	0.475	23	0.600	18	0.475
32/64	0.0982	18	0.594	23	0.750	18	0.594
24/48	0.1309	19	0.833	..	....	19	0.833
20/40	0.1571	20	1.050	..	....	..	....
16/32	0.1963	20	1.313	..	....	20	1.313
12/24	0.2618	22	1.917	..	....	..	....
10/20	0.3142	23	2.400	..	....	23	2.400
8/16	0.3927	24	3.125	..	....	..	....
6/12	0.5236	25	4.333	..	....	..	....

Maximum size of an external spline or serration is usually checked by a *go* composite ring gage, instead of pins, because such a gage inspects effective size, including errors of spacing (pitch) and parallelism (lead).

TOOTH-FILLET RADIUS: The spline standard lists an approximate, minimum fillet radius for various numbers of teeth and diametral pitches. The serration standard specifies radius of tool and mentions that resulting fillet will have a larger radius. It is desirable, for rolling, to have as large a tooth-fillet radius as possible. Table 8 gives recommended maximum root-fillet radii for rolled splines and serrations. These radii are tangent to the tooth profile and provide best rolling conditions, Fig. 5. The point of tangency between radius and tooth involute is called the TIF diameter.

Helical splines and serrations are considered special, and are not covered by the American Standard.

Preferred Number of Teeth: Rolling method used for external splines, and serrations with straight teeth, controls the smallest permissible diameters and minimum number of teeth, and varies according to diametral pitch. Through-feed rolling allows for fewer minimum number of teeth than in-feed rolling.

Fine pitches roll easier than coarse pitches on a given diameter. Design of a rolled spline or serration should provide, where possible, for more teeth than minimum required for rolling. A larger number of teeth permits better tracking of rolling dies on the blank and less strain on teeth of the dies. Under some conditions, shallower teeth are also specified for rolling economies. Use of preferred number of teeth and diameters will result in lower rolling-die cost per piece, and may reduce tooling costs for internal splines or serrations.

Certain manufacturing economies obtained in producing splines and serrations with cutting tools have resulted in specifications calling for as few teeth as possible. Introduction of the rolling process for forming teeth has offered large cost savings. Designers find it desirable to modify previously established rules for number of teeth to provide a condition more advantageous for form rolling, and at same time to maintain or improve torque capacity. Preferred minimum number of teeth and corresponding major diameters suggested for rolling different diametral pitches are given in Table 9.

This article is second in a group of three on thread and form rolling. The first, which appeared in the December 26, 1957 issue of MACHINE DESIGN, covered thread rolling. The third article in the group will be a comprehensive guide to selection of materials.

Tips and Techniques

Converting Temperatures

A handy rule for converting Centigrade temperature to Fahrenheit is to multiply the given Centigrade value by 2, subtract 10 per cent, and add 32.

Example: 100(2) = 200, 200 − 20 = 180, 180 + 32 = 212 F.

To convert from Fahrenheit to Centigrade, the process is reversed, i. e., subtract 32, multiply by 1.111, and divide by 2.

Example: 212 − 32 = 180, 180(1.111) = 199.98, 199.98/2 = 100 C. The actual equations involved are

$$F = 1.8C + 32$$

and

$$C = 0.556(F - 32)$$

—RAWL GERROW, *product designer, Milwaukee, Wis.*

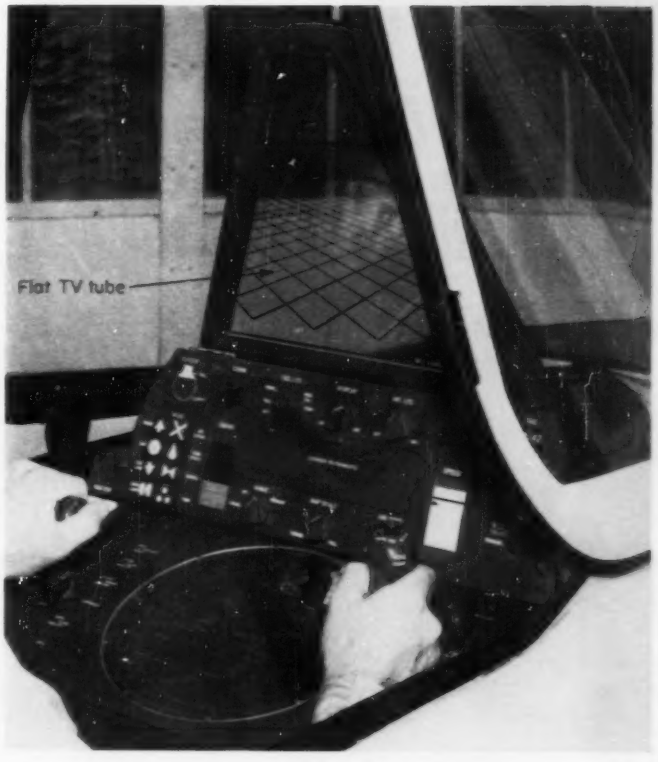
Do you have a helpful tip or technique for our other readers? You'll receive ten dollars or more for each published contribution. Send a short description plus drawings, tables, or photos to: Tips and Techniques Editor, MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

Flight Data Displayed on Flat TV Tube in Jet Cockpit

COCKPIT OF THE FUTURE is constructed with a thin, flat-plate TV tube developed by Kaiser Aircraft and Electronics Corp. Called a contact analog, the display tube is located directly in front of the pilot, much like a second windshield. Upon this transparent tube, which is only 2⅝ in. thick, is projected an artificial picture of the outside world.

Terrain and sky information are made up of grid lines or random dots which give the pilot a perspective type picture having third dimension qualities.

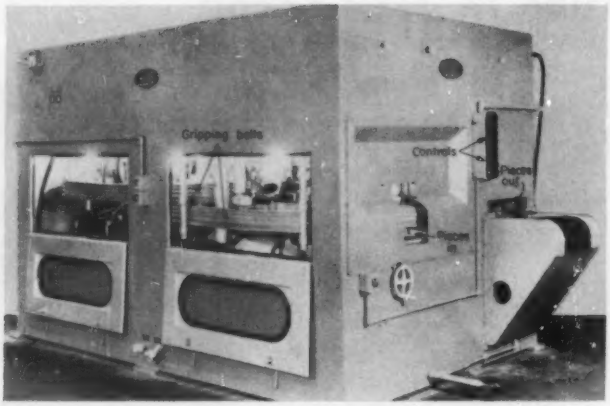
Although this is only a mock up plane, the forward cockpit of a two-place jet trainer has been equipped with such a flat TV-tube display and has been successfully flown by pilots at Douglas Aircraft.



SIMPLIFIED DESIGN OF CONTROLS in cockpit panel of future make it easier to fly jets. The "control stick" is quite short in length and is shown in the pilot's right hand. The pilot has his left hand on the throttle control.

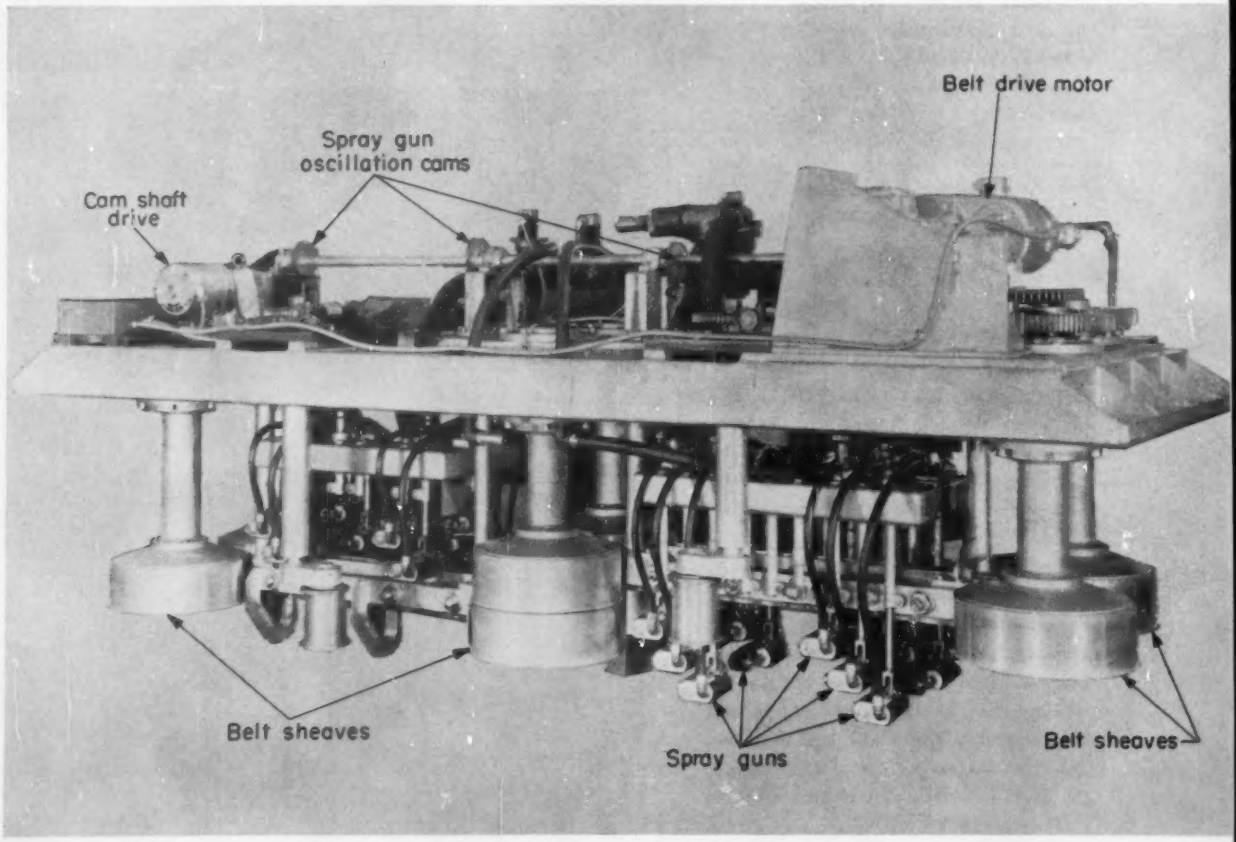
Signals for both the analog TV display and the horizontal navigational display in the jet trainer now being flown are provided by a digital computer designed and built by Litton Industries. Capable of making 15,000 computations per second, smaller than a bread box, and weighing less than 40 lb, the computer calculates the exact location of the aircraft 30 times each second.

Parts of Various Shapes Carried by

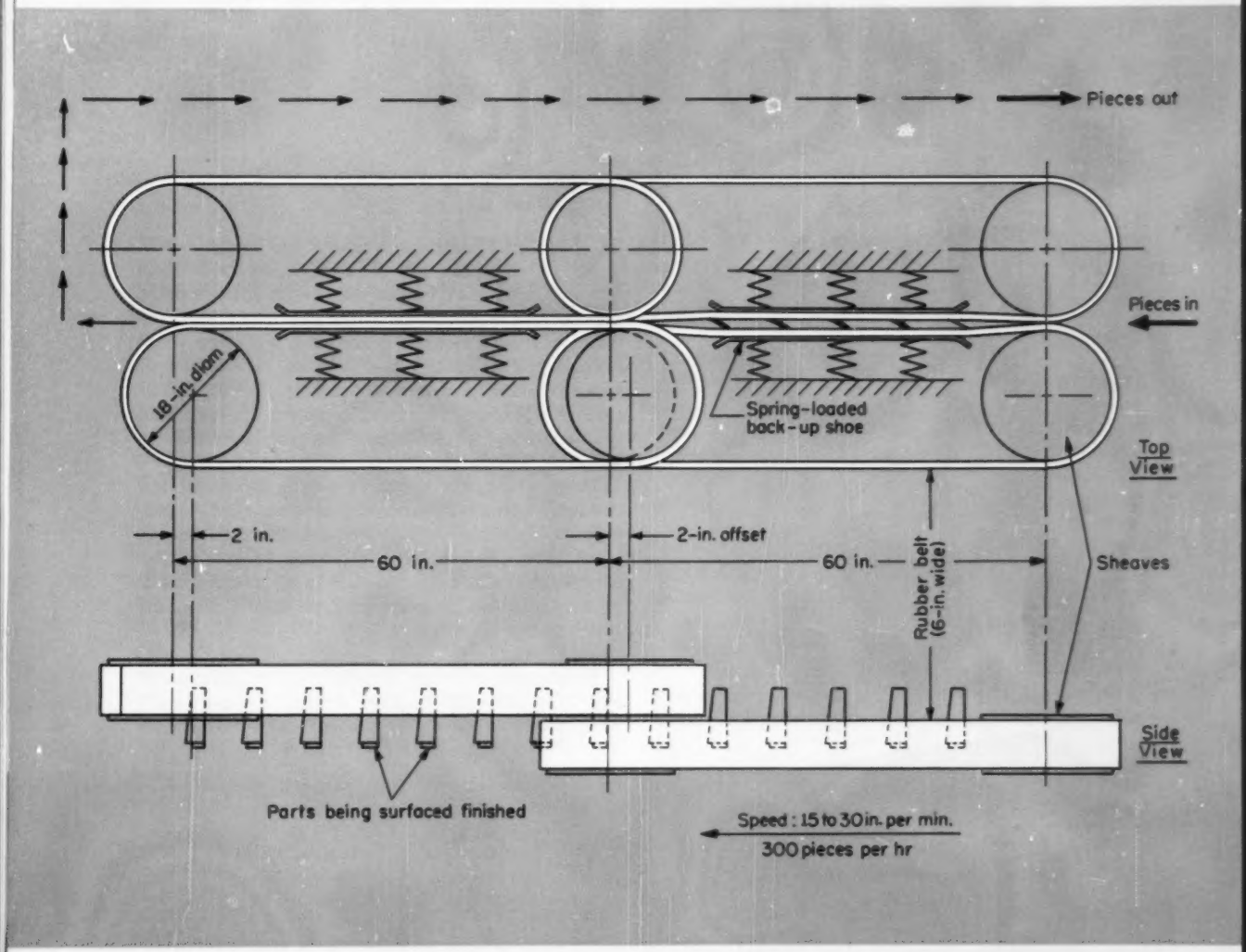


AUTOMATIC HANDLING of parts of different sizes and shapes is provided in the design of a new surface-finishing machine. Built by the Lewis Welding and Engineering Corp., Bedford, Ohio, the machine uses a liquid abrasive squirted from guns to give a microscopically smooth finish to aircraft, missile, and automotive components.

VERTICAL OSCILLATING MOTION is applied to the spray guns, providing a uniform abrasive-finishing effect on the parts. A motor-driven shaft with four eccentric cams mounted on it give the two sets of spray guns an up-and-down motion. Heavy springs keep the followers tight against the cams.

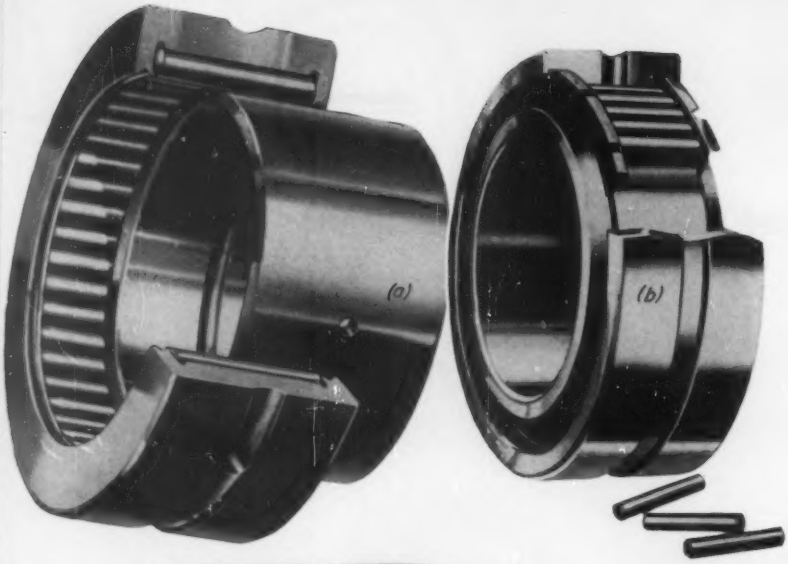


Flat, Grooved Rubber Belts



TWO INTERLOCKING SETS of moving rubber belts pick up parts to be finished and carry them past several sets of spray guns. Grooves of different widths in the belts make it easy to grip parts of all shapes. Two sets of spring-loaded back-up shoes also help to hold parts in the belts. The first pair of belts grasps the pieces so that their upper surfaces are exposed to high-pressure spray from the guns. When pieces move to the second set of belts, the bottom ends are exposed to spray from a second set of guns. As pieces are released from the second set of belts, they drop on a rubber conveyor belt, which runs at right angles to the grooved belts and at about 50 per cent higher speed. Parts are transferred again to an open-link type metal-belt conveyor and are carried through the rinsing compartment.

Rules for Application of



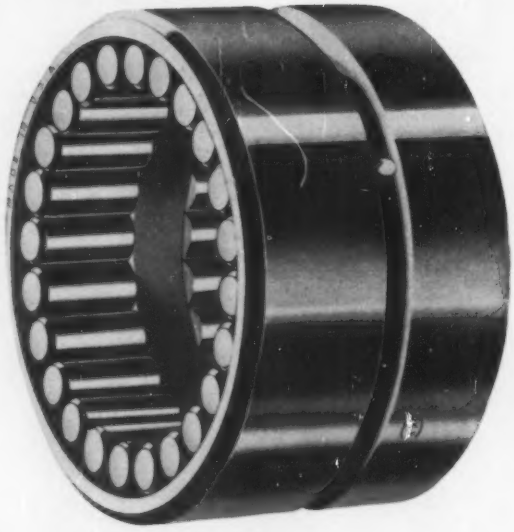


Fig. 1—Needle bearings are available in numerous types. Shown are full-complement with integral roller guide, *a;* full-complement with composite roller-guide construction, *b;* full-complement with center roller guide, *c;* and retainer type, *d.*

NEEDLE bearings confront the designer with a different set of application rules than those used for normal antifriction bearing applications. Needle bearings can carry high radial loads in a limited space and are usually applied where economy, heavy radial loads, and/or space limitations eliminate consideration of ball or cylindrical-roller bearings. However, for best needle-bearing performance, certain design rules must be followed.

There are many types of needle bearings, but the rules given will primarily concern needle bearings of the heavy-duty, end-guided, full-complement type, Fig. 1, although some of the recommendations will apply equally well to the center roller guide full-complement type and to retainer-type needle bearings.

Misalignment: The problem of misalignment, Fig. 2, is probably the most critical because needle bearings have somewhat limited ability to absorb

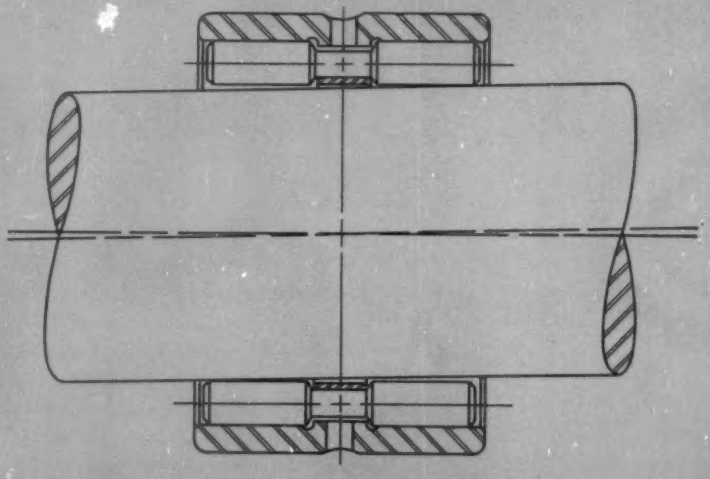


Fig. 2—Misalignment of shaft and bearing.

NEEDLE BEARINGS

By RICHARD SMITH
Chief Engineer
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the forces generated under such conditions. A full-complement needle bearing will withstand misalignment to a degree dependent largely upon load, since with an increase in load, there is an increase in the forces generated in the bearing and the accuracy in the surrounding machine members becomes more important. Most needle-bearing manufacturers have settled upon a theoretical misalignment of from 0.0003 to 0.0010 in. per inch of bearing width. However, this figure may be exceeded slightly when bearing load is light.

There are several modifications of full-complement needle bearings which either limit or overcome the detrimental effects of misalignment and deflection. One modification is the center-guide roller bearing, which tends to limit roller skewing. Another modification is the retainer type, which prevents roller skewing entirely and eliminates most, if not all, side effects of misalignment and deflection. The latter design does not have the load-capacity advantage present in full-complement needle bearings because the roller complement is reduced to provide space for the retainer. Slightly greater misalignment figures can be allowed with both these modified designs.

Deflection: The same general problems are present as in misalignment. In particular, the designer must design housings and shafts to be as rigid as possible to prevent excessive deflection. The misalignment figures given may be applied for deflection, remembering that lighter loads permit larger allowances.

Thrust Provision: Roller skewing is often present when either shaft or housing misalignment or deflection causes end loading of the rollers. This condition usually results in a thrust force being generated, reacting equally upon shaft and bearing. Uncontrolled roller skewing is often detrimental to an application. However, through proper design and provision of thrust plates, Fig. 3, the

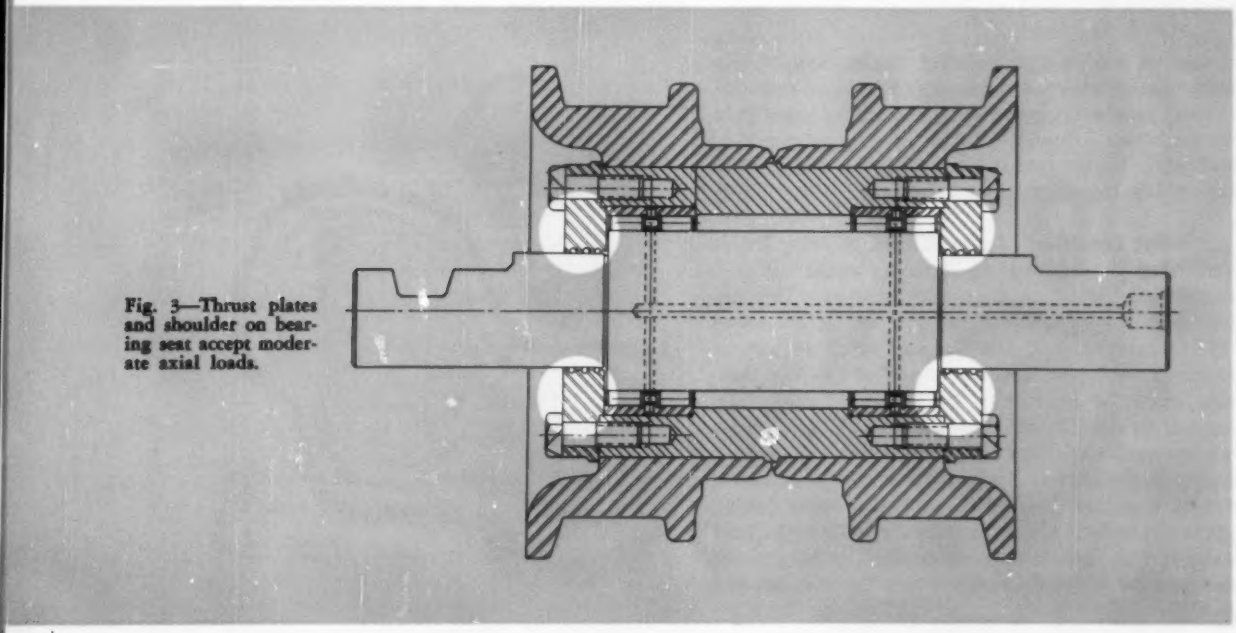


Fig. 3—Thrust plates and shoulder on bearing seat accept moderate axial loads.

Fig. 4—Right—Use of antifriction thrust bearing relieves needle bearing from heavy axial loads.

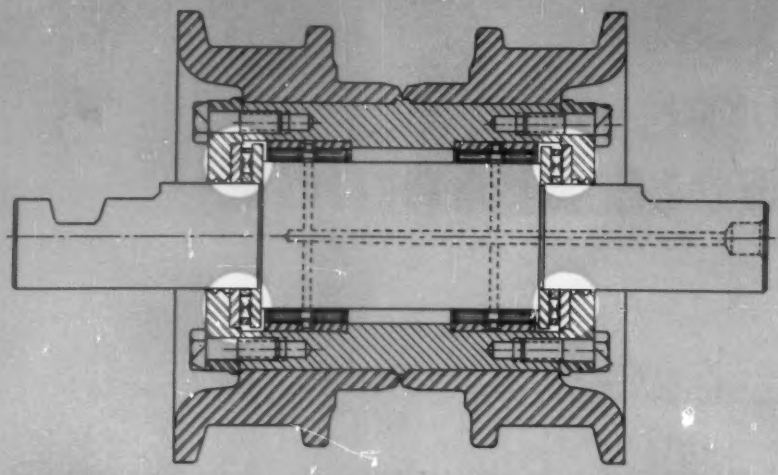
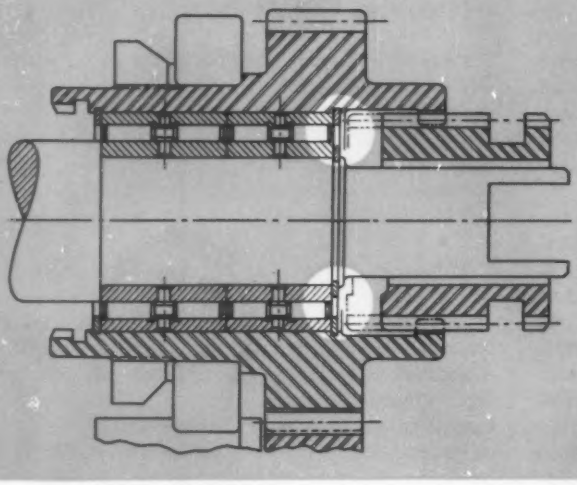


Fig. 5—Below—Snap rings are popular for fixing bearing location.



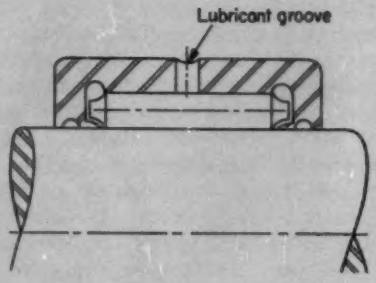
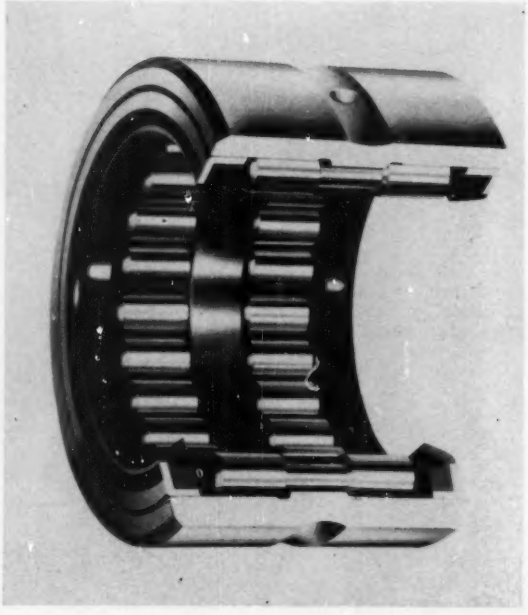


Fig. 6—Lips of needle bearing outer race form an effective labyrinth seal.

Fig. 7—Below—Both outside contamination and oil leakage are prevented by integral oil seals.

maximum load-carrying ability can be realized. In many cases where end loads are light, no special thrust provision is needed, but under moderate thrust a well-lubricated thrust washer is required, and with heavy thrust conditions an antifriction thrust bearing should be used, Fig. 4.

Bearing Location: As mentioned, skewing forces generated in the bearing have an equal and opposite end thrust on shaft and bearing. Depending upon the severity of roller skewing, either an interference fit with the housing or shaft will be required, or some physical means of bearing location must be provided. In general, bearing designers prefer to see both outer and inner races accurately located endwise with snap rings, Fig. 5, locknuts, or similar devices. For design economy where inner races are omitted, outer races can be press fitted into housings, usually with very good success. In general, recommended catalog press fits can be utilized except where bearing-loading conditions are extreme.



Lubrication: At one point during the early history of needle bearings, it was assumed that such bearings were usable only in applications where shafts were stationary or where only limited oscillation was involved. Subsequent tests and successful applications indicated that this was not the case. Depending upon the type of lubrication used, needle-bearing speed potential can be considered almost unlimited. However, there is one important factor for the designer to remember: With grease lubrication, the definite speed limits given in manufacturers' catalogs should be adhered to.

As in most antifriction bearings, very little actual lubricant is required to provide friction-free operation; the balance of the lubrication is to maintain satisfactory bearing operating temperatures. The amount of heat generated in a full-complement needle bearing is usually somewhat greater than in retainer-type roller bearings or comparable ball bearings. Thus, the potential operating speed with grease lubrication is usually somewhat lower for needle bearings.

With oil or oil mist lubrication, especially where an unlimited oil supply is available, more than enough cooling potential is available to keep bearing temperatures within normal limits, even under conditions of highest load and speeds. As a result, many applications have been opened for needle bearings where the speed was previously considered excessive. Speeds in excess of 10,000 rpm have been satisfactorily handled by needle bearings of 2-in. shaft diameter and larger. Actually, no top speed limit has yet been determined.

Sealing: Where contamination is not severe, needle bearings can usually be applied without exterior sealing, since the integral lips at each end of the bearing are a close running fit with the shaft or inner race and form an effective labyrinth seal, Fig. 6. Where sealing is necessary, needle bearings can be procured with integral oil seals, Fig. 7, giving protection against foreign-material contamination comparable to externally sealed applications. Sensitivity to foreign material in a full-complement needle bearing ranges somewhere between that of standard ball bearings and roller bearings, being less sensitive to contamination than the former and more sensitive than the latter.

Tips and Techniques

Solving Quadratic Equations

Quadratic equations such as $x^2 - Px + Q = 0$ can be readily solved with a slide rule. First, the equation is changed to the form $x + (Q/x) = P$. It should then be noted whether P is equal to the sum or the difference of the roots. P is equal to the sum of the roots if the value of Q is greater than zero. If P is greater than zero, both roots are positive; if P is smaller than zero both roots are negative.

P is equal to the difference between the roots if Q is less than 0. If P is less than 0, the smaller root is positive and the larger is negative. If P is greater than 0, the larger root is positive and the smaller is negative.

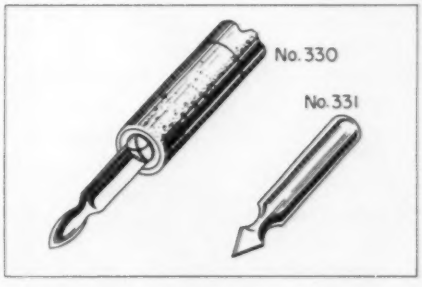
Set the index of inverted C scale over Q on the D scale. Then shift the slide until the sum (if sum of roots equals P; otherwise, the difference) equal to P, of numbers on the inverted C scale and the D scale, pass under the hairline simultaneously.

Example 1: $x^2 - 7x + 12 = 0$; $x + (12/x) = 7$. Since 12 is greater than 0 and 7 is greater than 0, both roots are positive and 7 is their sum. Set left index to 12, and shift slide until hairline crosses 3 on C scale and 4 on D scale simultaneously. The sum of these two numbers is 7, so they are the desired roots.

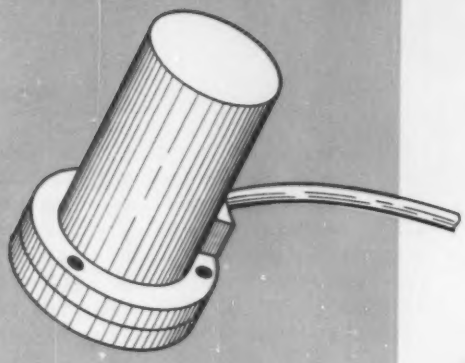
Example 2: $x^2 - 0.886x - 1.189 = 0$; $x - (1.189/x) = 0.886$. Since -1.189 is less than 0, -0.886 is the difference of the roots; the large root is positive and the smaller root is negative. Set index of inverted C scale over 1.189 on the D scale, 1.62 on D scale less 0.734 on C inverted equals 0.886. The roots are 1.62 and -0.734.—PETE PARR, *Cleveland*

Knives Correct Sepia Prints

A handy little time saver borrowed from the artist and retoucher is the scratch knife, such as the Esterbrook No. 330 and No. 331. These knives help in cleaning inked drawings when overrun



lines and small blots occur, and in removing unwanted details from reproducible films and sepias. The knives are held in an ordinary pen holder and may be resharpened on a fine-grain stone. They may be purchased in any art-supply store.—LAURELL F. ROTH, *lead draftsman, Fairbanks Morse & Co., Freeport, Ill.*



Design and operating characteristics of

Electromechanical Transducers

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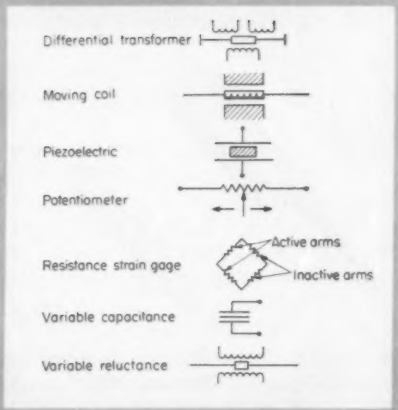
Electromechanical and electroacoustic transducers are devices which convert mechanical energy into electrical energy or vice-versa. Units which convert mechanical energy into electrical energy, often termed electromechanical pickups, are used to sense a variety of basic mechanical functions, such as force, pressure, displacement, velocity, and acceleration. By the sensing of these basic functions, such pickups are used to measure other important phenomena, such as impact, fatigue, stress and strain, pressure, and vibration, and are also used to control closed-loop systems.

The basic justification for the use of electromechanical pickups lies in the inherent versatility and high performance of electrical systems; the output of these devices can be fed to recorders, transmission systems, data-processing and analysis equipment, as well as automatic-process or flight-control systems.



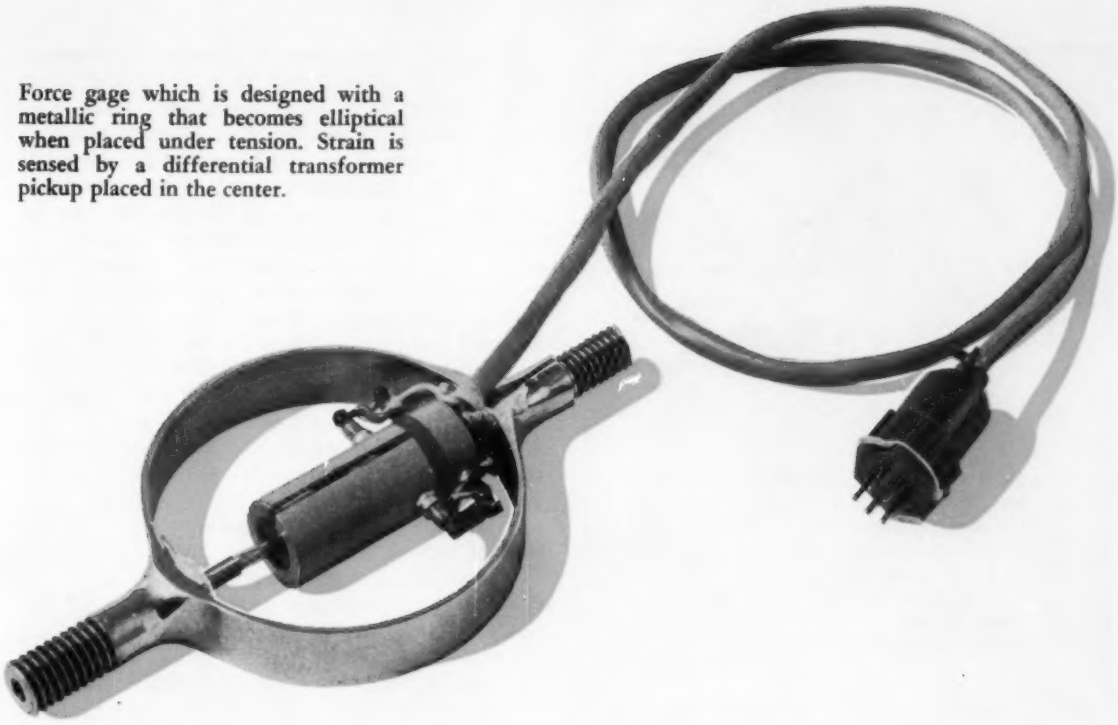
Electrical symbols for seven electromechanical converters or pickups.

TO BEST understand the design advantages and limitations of electromechanical transducers, it is important to know how such devices operate. In its simplest form an electromechanical transducer consists of two essential components—a mechanical linkage and an electromechanical converter or pickup. The mechanical linkage normally changes a mechanical input into a mechanical displacement or distortion, which is applied to the converter or pickup. Most electromechanical pickups operate on the basis of energy transduction principles of the piezoelectric element, the resistance strain gage, the differential transformer, the variable reluctance, the variable capacitance, the potentiometer and the moving coil.

Design and Performance Characteristics

One class of transducers cannot arbitrarily be considered better than another for all applications. Rather, the choice of transducer type will be a compromise of a number of factors. Furthermore, the designer should not judge the capability of any class of transducers solely by the instruments cataloged today. In short, with a clear understanding of the design and compatibility implications of transducers, the designer of instrumentation and systems can improve the compromises of his transduction system.

One important consideration in selecting and applying a transducer in design is the accuracy of transfer characteristics, that is, ratio of electrical output to mechanical input. These character-



Force gage which is designed with a metallic ring that becomes elliptical when placed under tension. Strain is sensed by a differential transformer pickup placed in the center.

istics are resonant frequency, damping coefficient, linearity, hysteresis and repeatability, and resolution.

Another important factor to consider is the physical loading effect on the mechanical system itself. This characteristic is determined by the mass of the transducer, the exterior size of the transducer, and the geometric configuration and compliance presented to the mechanical input.

Not to be overlooked are the effects of temperature, vibration, and other environments on accuracy, along with the expected life span or reliability under normal and overload conditions. The designer must study the auxiliary electrical power requirements, if any, which depend upon input electrical impedance, the type of the transduction principle, and the power-dissipation capability of the transducer.

Important, too, are the electrical output characteristics of the transducer, which depend upon the electromechanical transfer function of the device, the output impedance, and how the output signal is to be used.

Finally, the compatibility of this device with existing or proposed electronic or electrical systems of transmission, measurement or control must be considered.

It is difficult, if not impossible, to designate any one of these characteristics as being more important than any of the others, since this will depend upon the specific application.

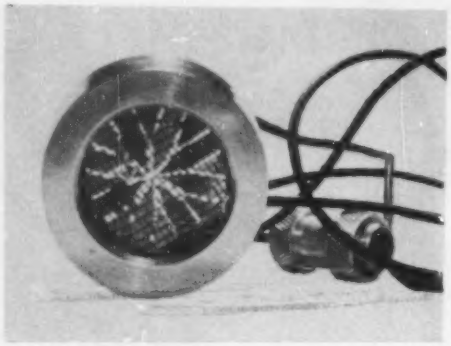
▶ Mechanical Linkage Designs

Sometimes it appears that the mechanical linkage produces another force rather than displacement, for in the case of a microphone having a solid piezoelectric slug behind a thin diaphragm, the force is actually produced on the piezoelectric element. To the microphone designer, this piezo-

Table 1—Nominal Limits for Typical Mechanical Open-Loop Linkages

Type of Linkage	Max. Useful Frequency (kc)	Max. Linear Displacement† (in.)	Maximum Range (psi)	Minimum Range (psi)	Acceleration Sensitivity
Flat diaphragm, loaded	2	0.020	2000	0.0001	High
Flat diaphragm, unloaded	100	0.020	2000	0.0001	Low
Convoluted diaphragm	500*	0.100	500	0.0001	Medium
Capsule	300*	0.250	500	0.0001	High
Solid pressure gage	500	0.00001	100,000	0.01	Low
Bourdon tube	1500*	0.100	10,000	10	High
Blocked tube	200	0.005	100,000	10	Low
Seismic	100	0.300	100,000‡	0.0001‡	.....

*Maximum useful frequency in cycles per second.
†These values do not include the use of lever devices to increase displacement.
‡Measured in gravitational units, not psi.



Gas-flow transducer fabricated of a short cylinder through which the gases pass. Suspended radially inward from the periphery of the cylinder are eight cantilever elements, which bend when the gas passes through. Amount of bending, and hence the rate of gas flow, is measured by small strain wire bonded to the cantilever surfaces.

electric element is a part of the mechanical linkage, and its own displacement or distortion is measured by another distinctly separate property —piezoelectricity.

The basic operation and characteristics of the various types of mechanical linkages are covered in the following section.

Types of Mechanical Linkages: Most commonly measured functions are force, pressure, extension, acceleration, velocity, and displacement. A variety of mechanical linkages are employed to reduce these functions to mechanical displacement.

FORCE: Normally, force is measured by distortion of a mechanical member stiffer than the forcing structure. A stiff rod, for example, may be placed in a testing machine, the rod being equipped with suitable strain-measuring converters. Another example is the so-called "proving ring," which is a stiff ring equipped with ears on opposite sides for fastening between cables under tension. This tension causes the ring to distort to an elliptical shape.

PRESSURE: Conversion of pressure to displacement can be accomplished in a variety of ways. Most common is the flat diaphragm, which bows under pressure. When more mechanical displacement is required to drive the electromechanical converter in a linear relationship, a convoluted diaphragm is used. Convoluted diaphragms may be welded in pairs along the periphery to form so-called capsules, which offer even greater linear displacement. Capsules may be joined in tandem fashion to create even greater linear displacement. Another common technique is the bourdon tube, a closed-end circular-shaped tube having an elliptical cross section, the radius of the circle increasing with internal pressure. Still another type is the elliptical cross-sectioned twisted tube, which tends to untwist under internal pressure. A further design is the simple closed-end tube, which tends to expand under internal pressure. A novel adaptation of this is the closed-end fluted tube, which has convolutions around its periphery.

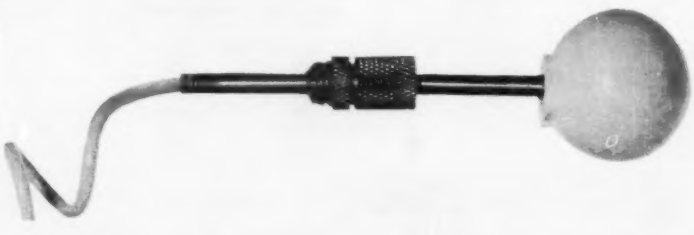
MECHANICAL DISTORTION: Measurement of mechanical distortion or displacement may be accomplished without the use of a mechanical linkage system, since the electromechanical converter can be affixed directly to the distorted member. Use of this technique depends primarily on the physical problem.

MOTION MEASUREMENT: Acceleration, velocity, or displacement of an object are often measured using a fixed point reference system; that is, a fixed object can be placed near the moving object and an energy converter used to measure the instantaneous displacement. Acceleration and velocity can be determined by electrical processing.

In many cases, however, seismic systems are used to measure the characteristics of motion. Such a system consists of a mass fastened to the moving structure by means of a spring. The forces of motion react against the mass and are evidenced by a distortion of the spring. Well below the resonant frequency of the seismic combination, the spring distortion is proportional to acceleration. Considerably above the natural resonant frequency, the spring distortion is proportional to displacement. In the mid-frequency range the distortion is a rather complex function of velocity.

Mechanical Linkage Characteristics: The mechanical linkage of a transducer is governed, to a large measure, by the mechanical input, and may have

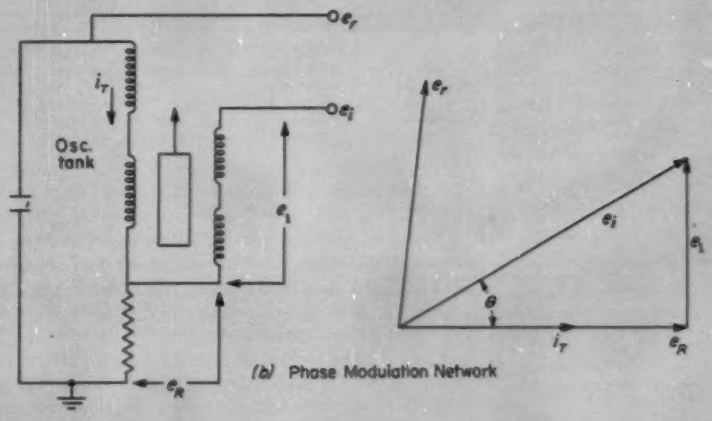
High-intensity piezoelectric microphone unit which consists of a hollow piezoelectric sphere suspended on the handle. In this instrument, the ceramic sphere acts both as the mechanical linkage and as the energy converter.



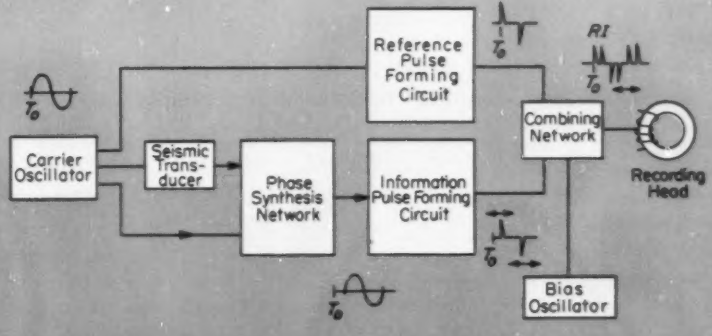
Missile Acceleration Recorder

Design problem involved the use of a differential transformer in a transistorized, magnetic-tape recording system to measure acceleration, Fig. *a*. The design solution centered around a pulse-time recording system which is first phase modulated. The system had to take best advantage of the transducer characteristics and eliminate most of the effects of nonlinearity and temperature-gain sensitivity of transistors. The circuit and basic operation of the phase modulation network is shown in Fig. *b*.

(a)



(b) Phase Modulation Network



(c) Block Diagram of Pulse-Time Recording System

The differential transformer in the recorder is excited with an ac carrier, and the current through the primary winding produces an in-phase voltage e_R. The output e_1 of the transformer is out of phase by 90 deg with the primary winding, but is proportional to the displacement of the seismic system. The sum of these two voltages, e_R and e_1, then has a phase angle θ which depends upon the magnitude of acceleration. This angle does not depend on the internal impedances of the transducer.

This phase-sensitive system is used in a circuit, the block diagram of which is shown in Fig. c. The carrier oscillator produces two voltages 90 deg out of phase, one going to a reference-pulse-forming amplifier and the other going to the phase-shifting transducer. Both signals are applied to limiting-and-differentiating transistorized amplifiers and are mixed in a simple resistive network to produce, at a repetition rate of 1000 cps, a series of four pulses. The relative timing of these four pulses is a measure of acceleration. In this manner, information does not depend upon transfer characteristics of the transistors. These pulses are applied to a magnetic tape, which is used in a completely integral tape recorder for airborne and missile measurements.

Example 1:—Assume that the following requirements are given for an accelerometer: 1. Acceleration range—±10 g full scale. 2. Frequency response—better than ±5 per cent from 0 to 20 cps. 3. Resolution—±1 percent full scale. 4. Sensitivity —5 v full scale at 1600 cps. 5. Input power—28 v dc for heating, —115 v at 1600 cps for excitation. 6. Linearity—±1 per cent of full scale.

PROBLEM SOLUTION: The requirement of sustained acceleration response eliminates the use of self-

Table A—Electromechanical Design Data for Required Accelerometer

Resonant Frequency, cps → / Damping Req'd, of Critical →		30 0.6 to 0.8	50 0.3 to 0.8	100 0.2 to 3	200 0.3 to 3
Type of Damping Suitable					
Magnetic		Yes	Yes	No	No
Temp. control		None	None	...	...
Fluid		Yes	Yes	Yes	Yes
Temp. control		±10 F	±30 F	None	None
Seismic Displacement*					
Per gravitational unit, in.		±0.010	±0.004	±0.001	±0.00025
Full scale, in.		±0.100	±0.04	±0.010	±0.0025
			Minimum Resolution of Energy Converter, per cent full scale		
	Min Displ., in.				
Variable cap.	$\pm 10^{-5}$	0.01—OK†	0.025—OK	0.1—OK	0.4—OK
Variable reluct.	$\pm 10^{-5}$	0.01—OK	0.025—OK	0.1—OK	0.4—OK
Diff. xfmr.	$\pm 5 \times 10^{-5}$	0.05—OK	0.125—OK	0.5—OK	2—OK
Potentiometer	$\pm 10^{-3}$	1—OK	2.5—NG	10—NG	40—OK
Strain gage	$\pm 10^{-5}$	0.01—OK	0.025—OK	0.1—OK	0.4—OK
			Maximum Deflection Range		
	Max Displ., in.				
Variable cap.	±0.030	NG†	NG	OK	OK
Variable reluct.	±0.030	NG	NG	OK	OK
Differential	>±0.5	OK	OK	OK	OK
Potentiometer	>±1	OK	OK	OK	OK
Strain gage	±0.005	NG	NG	NG	OK
Size in Shape of Cube, side length in in.		2½	2	1½	1
Weight, oz		12	8	4	1

*Seismic displacement $D_s = 10\ a/f^2$ where a is in gravitational units, f is in cps, and D_s is in in.
†NG means no good or not suitable. OK means the unit is suitable.

Table B—Characteristics of Units Suitable for 10-g Accelerometer

Characteristics	Type of Electromechanical Sensor Unit 1 Var. Cap.	Unit 2 Var. Cap.	Unit 3 Var. Rel.	Unit 4 Var. Rel.	Unit 5 Diff. Xfmr.	Unit 6 Diff. Xfmr.	Unit 7 Diff. Xfmr.	Unit 8 Potent.	Unit 9 Strain Gage
Damping	Fluid, no temp. control	Fluid, no temp. control	Fluid, no temp. control	Fluid, no temp. control	Fluid, 10 deg F control or magnetic	Fluid, 30 deg F control or magnetic	Fluid, no temp. control	Fluid, 10 deg F control or magnetic	Fluid, no temp. control
Resonant Freq., cps	100	200	100	200	30	50	100	30	200
Min. Resol., per cent full scale	0.1	0.4	0.1	0.4	0.05	0.125	0.5	1	0.4
Size in Shape of Cube, side length in in.	1½	1	1½	1	2½	2	1½	2½	1
Weight, oz	4	1	4	1	12	8	4	12	1
Compatability in System Design									
Electrical Excitation	1 kc to 10 mc	1 kc to 10 mc	60 cps to 100 kc	60 cps to 100 kc	60 cps to 20 kc	60 cps to 20 kc	60 cps to 20 kc	DC to 20 kc	DC to 20 kc
Circuit Connection	Bridge	Bridge	Bridge	Bridge	Direct	Direct	Direct	Direct	Direct
Full Scale Output, volts	1	1	1	1	50	50	50	100	0.1
Output Impedance, ohms	1,000,000*	1,000,000*	100	100	10,000	10,000	10,000	10,000	500
Cable Problems	Poor	Poor	Good	Good	Good	Good	Good	Excellent	Excellent
System Simplicity	Fair	Fair	Good	Good	Good	Good	Good	Excellent	Fair

*For a 100-micromicrofarad capacitor.

Table C—Suitable Accelerometer Designs* for Different Acceleration Ranges

Resonant Frequency, cps → / Acceleration Range, g →	30			50			100			200		
	±3	±10	±30	±3	±10	±30	±3	±10	±30	±3	±10	±30
Accelerometer Type												
Variable capacitance	■			■			■	■	■		■	■
Variable reluctance	■			■			■	■	■		■	■
Differential transformer	■	■	■	■	■	■		■	■			■
Potentiometer		■	■			■						
Strain gage							■				■	

*Color indicates the accelerometer type is suitable; no color means not suitable.

generating devices. Since the appropriate frequency response may be attained with various combinations of resonant frequencies and damping coefficients, a span of resonant frequencies must be chosen. For this particular set of requirements it is likely that instruments with resonant frequencies of between 30 and 200 cps might be used. Table A provides a set of further computations based upon arbitrary resonant frequencies of 30, 50, 100, and 200 cps.

The choice of resonant frequency has a direct bearing upon the required mechanical damping. Low resonant frequencies require closely controlled damping. Higher resonant frequencies require damping only for protection. A 30-cps unit would require magnetic damping or fluid damping controlled to within approximately ±10 F. A 50 cps instrument would require only ±30 F temperature control for fluid damping. A 100 or 200 cps unit would utilize fluid damping sufficient only to suppress resonance amplification.

The choice of resonant frequency also determines the seismic displacement as indicated in Table A. The seismic displacement is first used to determine whether the necessary resolution is attainable with each of the basic transducer systems. The systems which do not have resolution equal to or better than the requirements cannot be used. These data are also shown in Table A with "OK" for suitable and "NG" for unsuitable types.

The seismic displacement is also used to determine whether or not the displacement is too large to be measured without causing problems of nonlinearity, large size, or damage. This is done by comparing the seismic displacement with the "maximum deflection range" of the instrument. Results are shown in Table A as "OK" or "NG."

Instruments which satisfy the design requirements have been taken from Table A and their characteristics are summarized at the top of Table B. Out of the 20 instruments possible, nine meet the specifications from a basic design viewpoint. The choice of the proper instrument depends upon some of the other factors shown at the bottom of Table B.

If high voltage and circuit simplicity are paramount, the potentiometer unit, No. 8, could be used.

Of the other units the differential transformer unit with 50 cps resonance, No. 6, has excellent characteristics. The variable-reluctance accelerometers also would appear to be suitable, particularly if connected to a step-up transformer. From the user's standpoint, the variable-capacitance transducer is probably not as good as the others, because of its impedance and effects of cable loading.

Example 2: While Example 1 depicts the approach that could be taken for this specific problem, further data can be extrapolated from the chart. For example, if the acceleration range were decreased to ±3 g full scale, other factors being the same, the seismic displacement would be reduced by a factor of 3. Devices that would be suitable for the ±3 g range are listed in Table C for resonant frequencies of 30, 50, 100, and 200 cps.

Example 3: If the range were increased to ±30 g, other factors being equal, Table C also indicates the units that would be usable.

a direct bearing on the energy converter used.

Just as the entire transducer is "caught in the middle" between a mechanical forcing system and an electrical transmission system, so the mechanical linkage must produce from the mechanical input a sufficient displacement for use by the electromechanical converter. Table 1 indicates the mechanical conversion properties of several typical mechanical linkages. While these nominal values are to be considered rather arbitrary limits, they nevertheless indicate some important design factors, namely: 1. High-frequency linkages exhibit small mechanical displacement, but low acceleration sensitivity. 2. High-frequency linkages are useful for high input forces.

Factors which govern the design of the mechanical linkage are covered below.

FREQUENCY RESPONSE: Every mechanical linkage has physical mass and compliance, and these react to produce a fundamental free resonance. This resonance may be substantially lowered by mechanical loading, such as liquid loading of a diaphragm, or by mass loading due to the electromechanical converter, such as the core of a differential transformer. In general, simplicity of design and small size lead to high natural resonant frequency.

COMPLIANCE: A mechanical linkage should normally have high compliance to produce large amplitudes of motion. However, high compliance usually leads to low resonant frequency. Hence, compliance and resonant frequency usually are the result of compromise. In addition, a highly compliant structure is very susceptible to interfering and damaging effects of vibration.

MECHANICAL DAMPING: Often mechanical damping is used: 1. To increase the operating frequency range. 2. To reduce the effects of spurious resonances on accuracy. 3. To prevent overloading of auxiliary equipment. 4. To protect a sensitive system against damage.

Mechanical or acoustical damping may be introduced by various means—viscous-air, fluid, or magnetic damping. Magnetic damping, wherein energy is absorbed by a conductor moving in a magnetic field, has excellent thermal stability, but the limited energy absorbed by such a system limits its effective use to frequencies below approximately 45 cps. Fluid damping is used up to frequencies of 2 kc, but has the disadvantage of a high temperature coefficient of viscosity. Furthermore, it requires sealing and provision for pressure release. Viscous air damping is often used up to frequencies of 50 cps, but is nonlinear.

EFFECTS OF TEMPERATURE: Almost any mechanical linkage system is susceptible to a change in zero position and a change in sensitivity due to temperature change. It is indeed difficult to point out any one basic approach that is superior to another. In general, the effects of temperature are minimized by: 1. Use of materials with low temperature coefficients. 2. Elimination of organic

cements as far as possible. 3. Correlation of mating components on the basis of temperature coefficients. 4. Use of compensating or balancing devices.

One of the most difficult problems is the elimination of transient temperature effects. Compensating techniques alone are not generally sufficient to eliminate transient temperature effects because of thermal lag. More often a better approach is to eliminate thermal effects at their sources by judicious choice of materials and careful mechanical design.

NONLINEARITY AND HYSTERESIS EFFECTS: While nonlinearity and hysteresis effects cannot always be lumped together, these problems are essentially detail design problems; their reduction depends to a large measure in keeping the design simple, relatively rigid, and in a conservative range of strain. Avoid pivots and other frictional joints.

Electromechanical Converter Designs

Electromechanical converters or pickups may be divided into two classes—the self-generating class and the modulating or passive class. The former creates electrical energy as a direct result of mechanical input. The latter is a passive electrical device that changes its electrical properties because of a mechanical input, and hence requires excitation by electrical means.

A comparison of the properties of typical energy conversion devices is shown in Table 2. The most important characteristics are the limits of measurable displacement, the electrical output, and the circuit compatibility factors. While the variable capacitance and variable reluctance systems have somewhat similar characteristics, other devices are markedly different.

When connected to an electrical load, the self-generating types dissipate energy created by the mechanical input. As long as energy is so dissipated it must be resupplied mechanically. Since mechanical energy can be supplied only by a changing force, self-generating types are suitable only for dynamic measurements. The low-frequency limit of a self-generating device depends upon the electrical loading conditions as well as other sources of voltage, such as created by heat.

As an electrical generator, a self-generating transducer exhibits a true electromechanical conversion efficiency. At resonance, this conversion efficiency may approach 50 per cent. Below resonance, the conversion efficiency is normally considerably less than 5 per cent.

Passive, or modulation, types of energy converters obtain virtually all of their output power from the source of electrical excitation. For this reason they are suitable for producing output under sustained force inputs. These devices have a psuedoelectromechanical conversion efficiency, which is highly dependent upon the electrical exciting power. This electromechanical conversion efficiency, normally limited only by the heat dissipation capability of the device, may easily surpass 100 per cent.

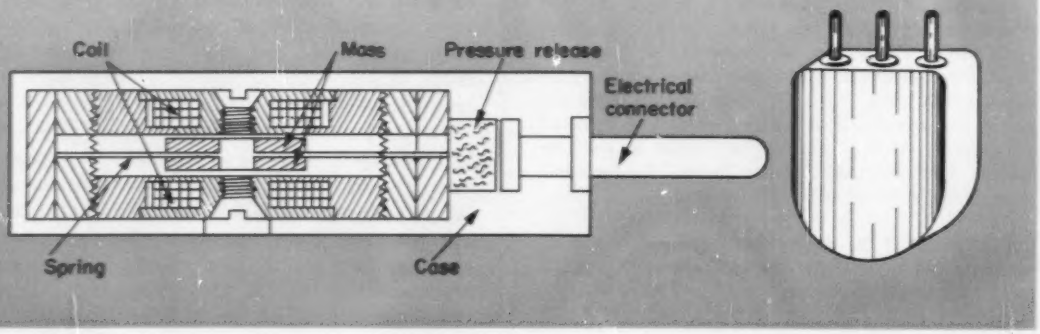
Self-Generating Energy Converters: Two types of active converters are in common usage—the piezoelectric and the emf coil generator.

PIEZOELECTRIC: A piezoelectric material is one which produces a voltage when subjected to mechanical strain. Materials which exhibit this characteristic include certain single crystals such as Rochelle salt, ADP, quartz, tourmaline, and certain polycrystalline ceramic materials, such as barium titanate.

The latter form of material is becoming more popular than the single crystals, and is available in a wide variety of configurations, such as rings, discs, or spheres, which can be tailored for the application. One of the most commonly constructed elements is the bender-sensitive device or Flexducer, which has considerably more mechanical compliance than other configurations.

Because of the high stiffness of piezoelectrics, these types of energy converters normally form

Subminiature variable-reluctance accelerometer. Within the housing are two windings placed in magnetic bobbins having ring gaps. In the center is a magnetic button mounted on a flat spiral spring. Acceleration in the vertical direction causes movement of the magnetic button, which increases one inductance while decreasing that of the other.



part of the mechanical linkage. They are particularly useful for attaining high resonant frequency. Materials in this class are already available for operation up to 500 F, and it appears that newer materials may prove useful to above 800 F.

EMF COIL GENERATING SYSTEM: The second type of self-generating converter is the emf-coil generating system which is a coil that moves in a magnetic field and creates a voltage proportional to velocity. Such devices are often mounted on very low frequency seismic systems, used above the resonant frequency. As such, they produce a voltage proportional to velocity.

Such devices are quite low in impedance and produce a substantial voltage. They are useful to relatively high temperatures.

Passive Energy Converters: There are several common designs of passive-energy converters including variable capacitance, variable reluctance, differential transformer, potentiometer, vibrating wire and electronic tube types. The latter two are not discussed here.

VARIABLE CAPACITANCE: In design, a variable-capacitance energy converter may consist of only an air capacitor, the position of one plate being controlled by the mechanical linkage system. In a typical microphone application, the movable plate is the sensing diaphragm.

The capacitance sensor is useful for high frequencies because there is virtually no loading on the mechanical linkage. The general disadvantage lies in small capacitance of the sensor.

VARIABLE RELUCTANCE: A sensor of the variable-reluctance type generally consists of one or more coils wound within magnetic bobbins having an air gap. The size of the air gap is controlled by a magnetic diaphragm or button, the position of which is controlled by the mechanical linkage. A variable-reluctance pickup does not produce loading on the mechanical linkage. Variable-reluctance systems utilize ac carrier systems.

DIFFERENTIAL TRANSFORMER: A typical differential transformer consists of a hollow concentric nonmagnetic form upon which are mounted three windings—one primary winding and two second-

Table 2—Characteristics of Energy-Conversion Devices

Characteristics	Variable Capacitance	Variable Reluctance	Differential Transformer	Potentiometer	Strain Gage	Piezoelectric
Type of device	Passive	Passive	Passive	Passive	Passive	Active
Electrical excitation freq. range	1 kc to 10 mc	60 cps to 100 kc	60 cps to 20 kc	DC to 20 kc	DC to 20 kc	None
Measureable displacement, in.	10^{-5} — 0.030	10^{-5} — 0.030	5×10^{-5} — 0.5	10^{-3} — 3	10^{-5} — 0.005	10^{-9} — 10^{-3}
Circuit connection	Bridge	Bridge	Direct	Direct	Bridge	Direct
Max. full-scale output, volts	1	1	50	500	0.1	5000
Output impedance, ohms	§10^6	§100	1000	10,000	600	2000*
Auxiliary equipment required	Carrier detector	Carrier detector†	Carrier detector†	None	Amplifier or carrier detector	Cathode follower
Mechanical loading on linkage	None	None	5-gm mass	Friction	Small	High stiffness

*Measured in micromicrofarads.
†May operate directly into control system.
§Will depend upon carrier frequency.

Table 3—Typical Limits of Accelerometers Based Upon Type of Energy Converter

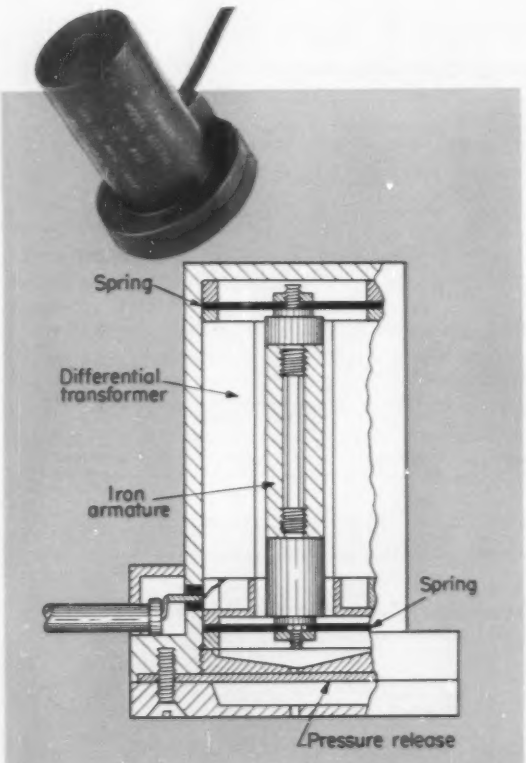
Type of Accelerometer	Acceleration* Range (g)	Frequency* Range (cps)	Accessories Required	Accuracy Incl. Linearity, Hysteresis, Repeatability (per cent full scale)	Nominal Temperature Range (deg F)
Piezoelectric	0.001 to 40,000	3 to 20,000	Cathode follower req'd for measurements below 200 cps	±5†	—65 to 500
Strain gage	0.01 to 1000	DC to 1500	Carrier excitation (AC or DC)	±1	—65 to 350
Variable reluctance	0.1 to 1000	DC to 3000	Carrier excitation	±3	—65 to 265
Variable capacitance	0.1 to 1000	DC to 3000	Carrier excitation	±3	—65 to 265
Electronic	0.01 to 75	DC to 300	Stable power supply and zeroing control	±2	—65 to 250
Differential transformer	0.01 to 1000	DC to 500	Carrier excitation	±1	—65 to 265
Potentiometer	0.2 to 75	DC to 60	Excitation (AC or DC)	±2	—65 to 265

*These ranges are not for one instrument, but for several in each category.
†Per cent of reading.

ary windings. A core is placed within the coil form and its position determines the relative coupling between the primary and each of the secondary or output windings. When excited with a carrier and with the output windings connected in series opposition, the phase and magnitude of the output is a direct measure of the displacement of the core from its position of null.

POTENTIOMETER: In construction, a potentiometer consists of a mandrel with a closely wound wire placed on it. The unit is supplied with a wiper, and when the unit is excited with a voltage, the position of the wiper determines the amplitude of output voltage. The potentiometer has extremely high output, but has a limited resolution and exhibits wear over extended periods of time.

UNBONDED STRAIN GAGE: When wire is tightly wound between two points, a change in separation of the points will strain the wire and change its electrical resistance. These unbonded strain gages may be excited by either ac or dc, and exhibit excellent hysteresis characteristics. Their primary limitation is low output voltage.



Differential-transformer accelerometer built with a seismic system suspended on flat spiral springs. Acceleration in the vertical direction causes a displacement of the suspended iron armature from its null position, producing an output from the differential transformer surrounding this core.

Characteristics of Seismic Transducers

From Table 2, it is evident that the various converter systems will provide a wide variety of characteristics when designed into transducers. Table 3 describes the characteristics of seismic accelerometers based upon the conversion devices described. Of major importance is the fact that no one type is best for all applications. For dynamic measurements, particularly at high frequencies, the piezoelectric devices are best, because they are extremely rugged and their accuracy is a constant percentage of the actual reading rather than a fixed percentage of full scale.

Of the other types, the potentiometer is useful where a high-voltage output is important and long life is of secondary importance. The choice of strain gage, variable reluctance, or differential transformer is determined mainly by the output requirements of the transducer.

Transducer Design Steps

To the transducer user, no instrument is perfect, although several types may satisfy a requirement. When a problem arises, what can be done to determine the best approach for the instrument design? One logical approach is to first design the mechanical linkage system and then choose the various types of converters for use with it. When this has been done, one instrument can be chosen which best satisfies the other problems of compatibility. If none satisfy acceptable compatibility requirements, the electromechanical specifications must be revised and the procedure carried out again.

To illustrate the preceding approach as well as to indicate some of the design implications, three typical examples are presented. It is extremely important to note that the assumptions upon which the calculations are made in these examples are considered as practical limitations of certain types of designs. The minimum resolution of certain of the energy converters, for example, may depend upon choice of specific designs of the converter since, again, the maximum deflection range is greatly dependent upon space and size limitations. It has been necessary, however, to set practical limitations on these techniques in order to, first, describe the approach a designer takes in creating an instrument, and second, to provide a working span for practical limitations of such devices.

The factors of compatibility cannot be overlooked in the choice of a transduction system, for they may have considerable bearing on the overall system simplicity, reliability, and accuracy. Such factors which contribute to the final choice are: 1. Temperature range. 2. Lead lengths. 3. Available electrical power. 4. Electrical excitation frequency. 5. Amplitude and impedance level of the required output. 6. Available space.

What are the design factors to be considered in specifying worm gearing? Characteristics of these gears permit wide latitude in possible designs. In turn, this advantage requires designers to exercise judgment to a proportionate extent.

Decisions on worm gearing are sometimes influenced by inaccurate generalizations. One is that worm gears are inefficient. To dispatch this at the outset, it should be observed that certain worm gears, of ratios comparable to those of conventional gear sets, operate at 97 per cent efficiency.

Considerations summarized here will help in selecting and specifying the dimensions and properties of worm gears for particular applications.

Specifying Worm Gearing

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PROBABLY the most important factor controlling the design of worm and gear pairs is the relationship between the worm and the hob for generating the gear teeth. Since the gear must envelop the worm, Fig. 1, the worm-gear hob must be essentially a replica of the worm in diameter and tooth form. Therefore, in general, each design of worm requires a particular design of hob. Wherever practical, therefore, it is desirable to specify a worm design for which a hob exists.

Another characteristic of worm gearing, responsible for variation in design, is that pitch diameters of the worm and gear are not proportional to the reduction ratio. This permits the use of a single, compact set of gears for a large ratio of speed reduction. The same characteristic is responsible for a wide choice of diameters for a particular basic size.

Physical Dimensions: Basic size is normally determined by power requirements and materials employed. AGMA Standard 213.02 provides a rating

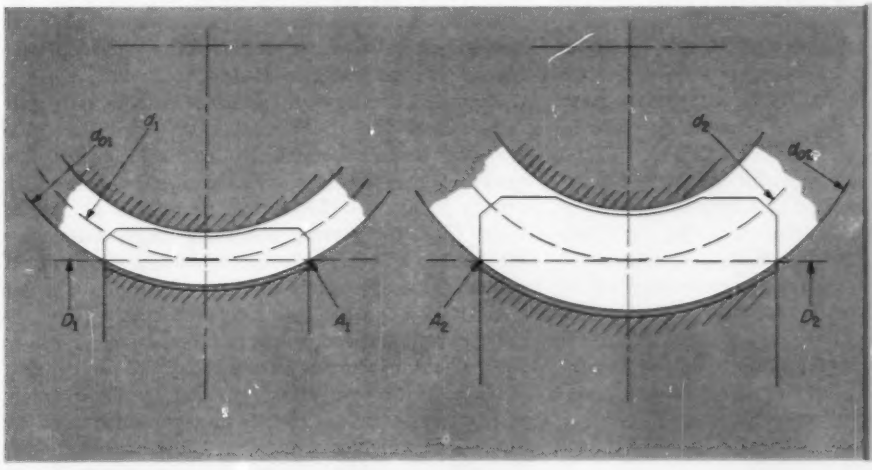

Fig. 1 — Graphical method of determining effective gear face width, F_e. Also shown is the effect of pitch on effective gear face width. Extent of F_e is determined by the intercepts, A_1, A_2, between a line tangent to the worm pitch circle and normal to the line of centers.

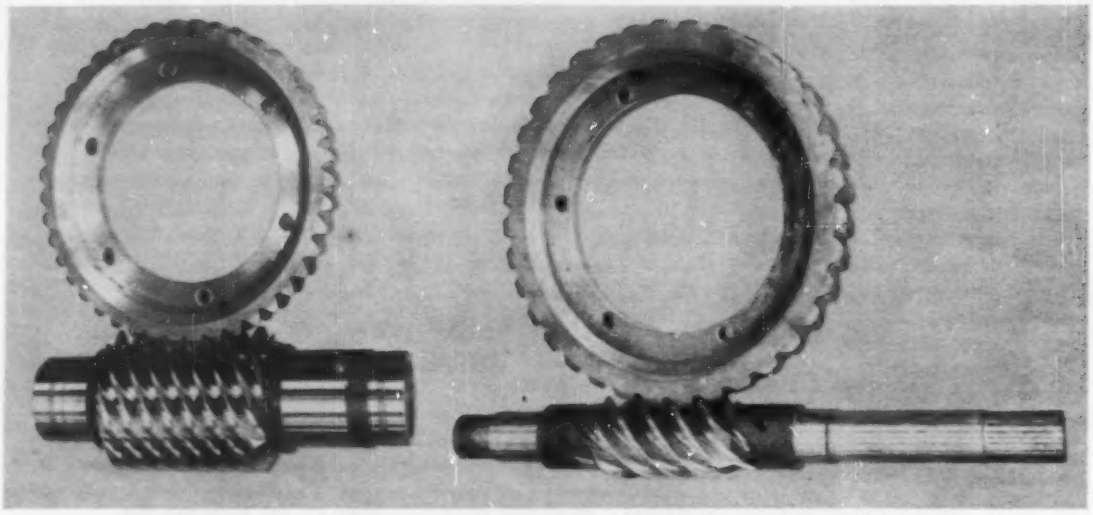

Fig. 2—Two worm gear pairs illustrate range of variations of designs. The pairs have essentially the same ratio and center distance but different proportions.

method for gearing of the most commonly used materials (carburized-steel worm and tin-nickel-bronze gear). In some instances, dimensions of connected equipment or index accuracy requirements control size rather than the amount of power transmitted.

Knowledge of the application requirements and consideration of the factors in Table 2 will aid selection of an approximate worm pitch diameter.

For most applications, the worm root diameter is kept as small as consistent with strength and deflection. In the most effective design, the worm is made integral with its shaft and is supported by bearings mounted at a short span. In some instances, it is necessary to bore the worm for mounting on a separate shaft, which dictates an abnormally large worm diameter. Fig. 2 illustrates two designs of essentially the same ratio and center distance but of vastly different proportions.

Once an approximate worm pitch diameter and a center distance have been established, the gear pitch diameter may be determined, Equation 4.

It is common practice to calculate an exact gear pitch diameter by Equation 2 after selection of a circular pitch which can be factored into a lead gear fraction. The magnitude of the pitch is governed by the approximate gear pitch diameter and the number of gear teeth. Several trials may be required before the desired combination of dimensions is determined.

Since the reduction ratio is the number of gear teeth divided by the number of worm threads, the values for these proportions will be selected simultaneously. As a guide toward proper design, AGMA Standard 340.01 lists recommended minimum numbers of gear teeth, Table 3. The use of smaller numbers of teeth than recommended could result in loss of overlapping tooth action or, in the case of low ratios, undercutting of the gear teeth.

Selection of the number of teeth, in addition to being influenced by these considerations, will be affected by the application. If the application involves slow speeds and heavy loads, a small number of gear teeth and a relatively coarse pitch will offer some advantages. In addition to providing a heavier tooth section, the coarse pitch permits using a wider gear face as Fig. 1 illustrates.

On the other hand, higher speed applications may favor the use of a larger number of teeth and finer pitch. In general, finer teeth can be more accurately generated and they insure smoother operation. In addition, sliding velocities at the worm thread tips are lower in view of the shallower tooth depth.

In the design of low ratio gearing, particularly where the lead angle of the worm is greater than 30 degrees, additional precautions should be taken. As indicated by Fig. 3, the pressure angle of the worm gear tooth varies at different sections. At the point where the worm thread leaves mesh, this angle is much smaller than at the entering section. To avoid undercutting of the gear teeth by the worm threads, it is common practice to stub the teeth and resort to higher worm thread pressure angles. Wide faces should also be avoided since their use results in a greater variation in pressure angles along the tooth.

Equation 6 affords a means of determining gear face width for the average application. This formula provides an analytical solution of the graphical means of determining effective face width shown in Fig. 1. Little can be gained by use of wider faces for gearing operating under continuous loading at input speeds corresponding to those of commonly used electric motors.

However, the use of wider faces may be indicated for slow speed, heavy torque service or where severe peak loading is encountered. The increasing of face width over that provided by Equation 6, in any case, provides results in accordance with the law of diminishing returns. Increase in power

Table 1—Nomenclature and Equations

Addendum (worm or gear),* in.
$$a = 0.318\ p_x \quad (1)$$

Gear pitch diameter, in.
$$D = \frac{N_g\ p_x}{\pi} \quad (2)$$

Gear throat diameter, in.
$$D_t = D + 2a \quad (3)$$

Worm pitch diameter, in.
$$d = 2C - D \quad (4)$$

Worm outside diameter, in.
$$d_o = d + 2a \quad (5)$$

Effective gear face, in.
$$F_e = [(d + h_k)^2 - d^2]^{1/2} \quad (6)$$

Working depth (worm or gear),* in.
$$h_k = 0.636\ p_x \quad (7)$$

Whole depth (worm or gear),* in.
$$h_t = 0.686\ p_x \quad (8)$$

Lead of worm threads, in.
$$l = N_w\ p_x \quad (9)$$

Lead angle of worm, degrees
$$\lambda = \tan^{-1}\left(\frac{l}{\pi d}\right) \quad (10)$$

Additional Nomenclature

C = Center distance, in.
N_g = Number of teeth in gear
N_w = Number of threads in worm
n = Worm speed, rpm
p_x = Axial pitch of worm, degrees
V = Rubbing speed, fpm
θ = Friction angle, degrees

*These are arbitrary values commonly used where lead angle is less than 30 or 35 degrees. Where lead angle is higher, stubbing of teeth is often necessary.

Table 2—Factors Affecting Selection of Worm Pitch Diameter

Small diameter:

1. Provides larger lead angle with resultant increase in efficiency.
2. Reduces sliding velocity between worm threads and gear teeth, thereby increasing power capacity in the high speed range.

Large diameter:

1. Increases rigidity and reduces bending stress (worm considered as simple beam under action of gearing forces).
2. Permits utilization of wide gear face.
3. Provides lower reversed efficiency where locking or braking characteristics are desired.

Table 3—Recommended Minimum Numbers of Gear Teeth for General Design

Center Distance, in.	Number of Teeth*
2	20
3	25
5	25
10	29
15	35
20	40
24	45

*Lower numbers of teeth are permissible for specific applications.

capacity is therefore not proportional to the increase in this dimension.

Efficiency: Many factors affect the efficiency of worm gearing. Dimensions of importance are: Lead angle, pressure angle, and worm diameter. Coefficient of friction has a great effect on efficiency in view of the sliding contact between worm thread and gear teeth. This factor varies in value with: Worm and gear materials, surface finishes, rubbing velocity and lubricant.

Efficiency can be determined as shown in Fig. 4. It is emphasized that the relationship for coefficient of friction covers specific conditions as noted. The equations assume pressure angle to be zero. This is not absolutely correct, but the error in calculated efficiency is very small.

Reversed efficiency covers the case where the gear drives the worm. Worm gears having lead angles in the range of 25 to 45 degrees and operating at high speed have reversed efficiencies only slightly less than those for the worm driving. However, as lead angle and speed decrease, the disparagement between efficiencies becomes greater. Should the lead angle be less than the friction angle, reversed efficiency will be zero and the condition referred to as "self-locking" will exist.

This condition, which occurs only with high ratio gearing and under static or low speed conditions, is sometimes utilized as a brake. However, a

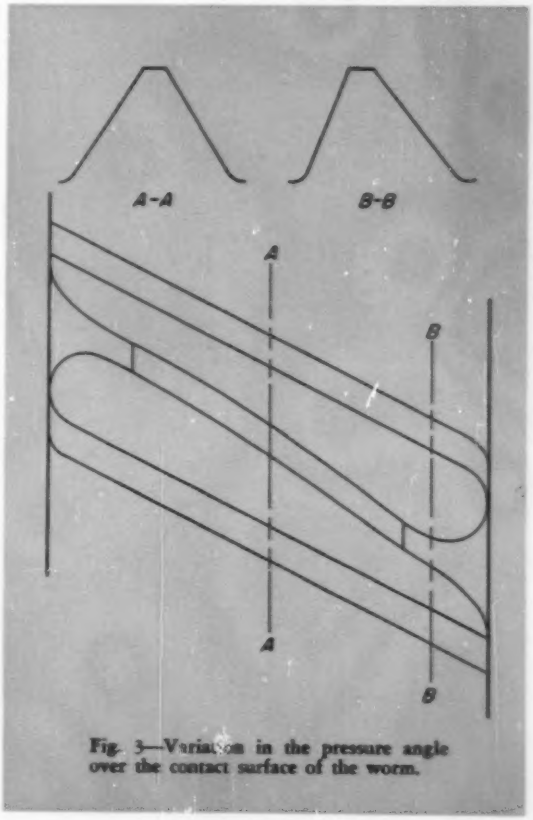

Fig. 3—Variation in the pressure angle over the contact surface of the worm.

factor of safety should be introduced by assuming the coefficient of friction to be less than theoretical data would indicate. Since the value of the coefficient is affected by many variables it is difficult to predict its magnitude for a specific set of conditions. Furthermore, conditions may change. For example, a locked set under static conditions may be set in motion by vibrations which would decrease the coefficient of friction because of the slight movement at the contacting surfaces.

Reversed efficiency is also important in applications where high inertia loading may be applied to the gearing if motion is suddenly stopped. For example, a high ratio worm gear drives a turntable, which has a moment of inertia of large magnitude. A brake is applied at the input shaft to stop the turntable at a certain point. Reversed efficiency and strength of the gearing must be considered in selecting the brake to avoid excessive stress which might occur from a rapid deceleration of the high inertia load.

Materials: Besides strength and wear resistance, frictional or bearing properties also influence selection of worm and gear materials. The most common combination in use is: For the worm, a low-carbon alloy steel carburized and hardened; for the gear, tin-nickel-bronze. These materials provide excellent results at rubbing velocities to 6000 fpm.

Certain of the harder, higher strength bronzes, such as aluminum and manganese bronzes, can be applied successfully at low rubbing speeds. However, due to poor bearing qualities, their application is definitely limited. An exact speed limitation on these materials is difficult to establish because of the number of variables involved and the effect of worm lead angle on operating results. A safe limit for rubbing velocity is 500 fpm.

Cast irons as worm gear materials have little application other than for slow speed or lightly loaded gearing. This type of material is difficult to "run in" because of its poor conformability compared with tin-bronze. Operating results vary considerably and very little information is available on load-carrying ability.

In addition to carburizing grades, steels of lower surface hardness are suitable for intermittent operation, particularly at low speeds where wear resistance is not so much of a factor. For applications involving extremely high peak loads a medium-carbon alloy steel, hardened to approximately 400 Bhn, may be superior to a carburized steel. Such extreme pressures as encountered in gearing which drives the roll adjusting "screwdowns" on metal finishing mills may be sufficient to cause cracking of a carburized case. Steels of even lower surface hardness are used on many applications—for example, elevator hoist drives.

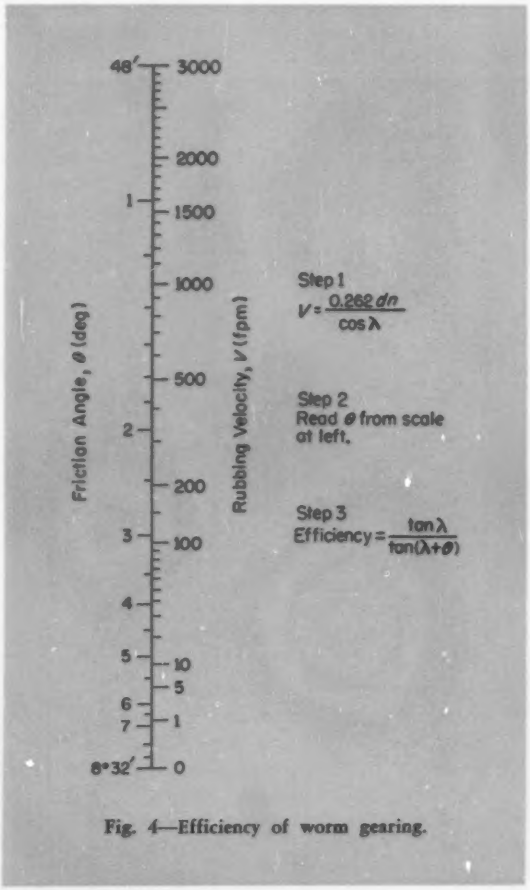

Fig. 4—Efficiency of worm gearing.

Blacklash: In any type of gearing a certain amount of backlash is required for satisfactory operation. Clearance must be provided to accommodate an oil film, and to allow for thermal expansion, errors of spacing, and concentricity.

The amount of blacklash provided is not of particular importance in most applications. Closer limits than required will, of course, result in unnecessary higher costs and therefore should be avoided. On the other hand it is important to recognize where minimum backlash may be required to insure proper equipment functioning.

Close limits are most often specified for accuracy of index or timing. In other instances it may be advantageous to specify minimum backlash for the purpose of limiting the stress at the gear teeth caused by shock loading. Where shock load of a reversing nature causes the gear to override the worm, stresses will be increased greatly if clearance between gear teeth is increased.

"Every true research project contains an element of risk. If there is no risk there can be no unknown factors present and, without the unknown, there is no research. While risk can never be eliminated from research, it can be reduced by systematic and periodic reviews of the critical (technical and economic) factors involved."—EMIL OTT, *director of research, and* CARL PRUTTON, *executive vice president, Food Machinery and Chemical Corp.*

A practical approach to accurate determination of Tightening Torque for Bolts

By RICHARD SKIDMORE
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ADVANTAGES of prestressing or preloading bolts in assembly are well recognized. Ideally, initial bolt tension should be a maximum as governed by practical strength limitations of the connected parts or the nut and bolt assembly, Fig. 1. The greater the clamping force developed, the less will be the tendency of parts to creep or shift. In addition, proper tightening will prevent continual loading and unloading of the bolt, a condition which can lead to fatigue failure. Moreover, the possibility of the nut backing off or loosening in service will be greatly reduced.

On the premise then that a bolt should be neither too tight nor too loose, the basic question in design becomes: How much tightening torque is required to develop optimum bolt tension? Here is a practical approach to the problem that offers accurate results under varying design and application conditions.

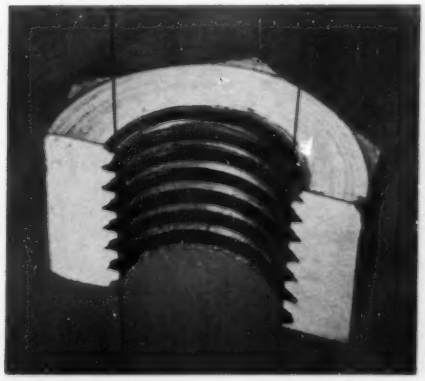
Basic Concepts: Consider first the manner in which torquing energy is distributed when a bolt is tightened by holding the nut and applying torque to the bolt head. If the hole alignment is correct, thread fit is not too tight, and clamping surfaces are approximately parallel, it has been shown that torque energy is distributed in three ways. About 50 per cent of the torque is absorbed in overcoming friction under the bolt head. At this point, there is a sliding action under tremendous pressure. Approximately 40 per cent of the torque is absorbed in overcoming friction in the threads, another point where there is a high sliding friction.

Only about 10 per cent of the applied torque creates tension in the bolt itself. Thus, relatively small changes in the friction under the bolt head,

Table 1—Effect of Different Nut and Washer Combinations on Torque-Tension Relationship

Type of Nut*	Type of Washer	Tension at 23 lb-ft Torque (lb)	Torque at 4400 lb Tension (lb-ft)
Soft steel, nonlocking	Soft steel, plain	4400	23
Soft steel, nonlocking	Hard, spring-lock	5100	20
Case hardened, nonlocking	Hard, spring-lock	5500	18
Soft steel, nonlocking	Hard, serrated	3900	25
Prevailing-torque locknut	Soft steel, plain	4400	23
Prevailing-torque locknut	Soft steel, plain	4700	22
Prevailing-torque locknut	Soft steel, plain	1800	30
Prevailing-torque locknut	Soft steel, plain	3600	27

*All nonlocking nuts are heavy type; locknuts represent four different commercial designs.



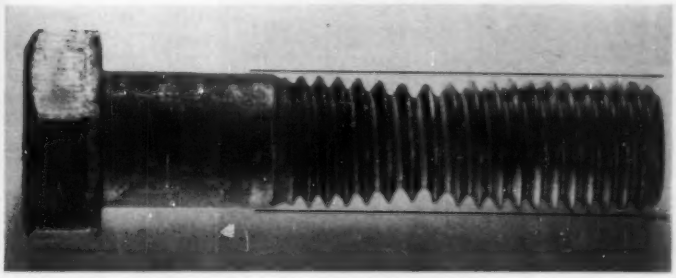


Fig. 1—Effect of overtightening bolt and nut assemblies. Bolt has been stretched and weakened by excessive tension developed. In nut, partial stripping of threads and distortion of ID has occurred.

or in the threads, may well have considerable effect on the resultant bolt tension for a given applied torque. Specific examples of this variation are tabulated in Table 1.

Torque-Tension Data: To accurately relate applied torque to actual bolt tension, a bolt-tension calibrator must be used. A typical unit of this type is shown in Fig. 2 and will be used here for illustration.

When a bolt is tightened in this instrument, induced tension is shown directly on a calibrated gage. Samples of bolts, nuts, washers, etc., from the fabricator's actual stock are used in setting up torque standards. Thus, all variables of the actual assembly—such as thread roughness, plating, class of thread fit, type of nut, thread lubrication, speed of tightening, material and hardness of surface under the bolt head—may be duplicated in the calibrator.

The following test procedure is suggested:

1. Mount bolt in calibrator to duplicate torquing conditions (bolt or nut) of actual assembly.
2. Use a washer of the same material as will be used in the assembly. If no washer is used in the assembly, it is recommended that a washer of the same material which the bolt head or nut bears against in the assembly be used.
3. Use the same nut as in the actual assembly. If a tapped hole, rather than nut is used in the assembly, a nut must be made employing the same material, tap drill size, and class of tap as the tapped hole.
4. Tighten the bolt by torquing with an accurate torque wrench. Record readings of both torque and bolt tension as the bolt is tightened, continuing until no further increase in tension is observed with further turning of the bolt head.

Typical data are shown in Table 2. These values present the average of six tests, using the foregoing procedure.

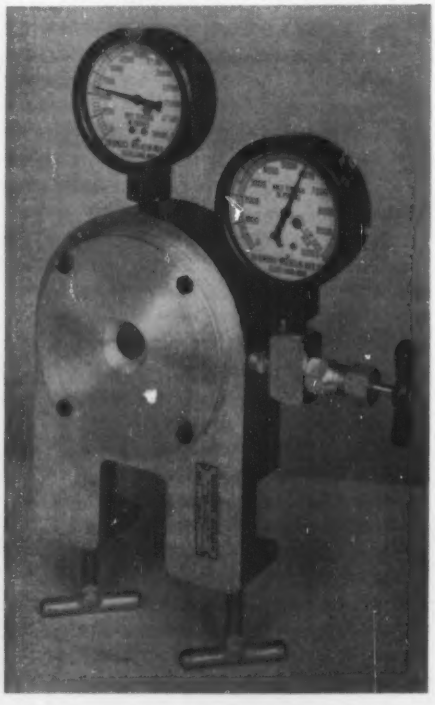
Although the procedure just outlined has been related to a specific type of calibrator, the general principles for setting up a torque standard are applicable to any testing device used.

Application of Data: Ultimate-strength values for standard bolts of different materials are given in Table 3. In determining torque standards for prestressing bolts at assembly, it is recommended that bolts be loaded to 70 per cent of these strength values for most applications. This preload may seem high, since most design analyses call for a much lower working stress. However, analysis of Fig. 3 will show the reason behind this recommendation.

Data in Table 2 are the results obtained with a heat-treated (120,000 psi), medium-carbon steel bolt of 5/16-in. diameter, having 18 threads per inch.

Table 2—Torque-Tension Data

Torque (lb-ft)	Tension (lb)	Torque (lb-ft)	Tension (lb)
0	0	21	4000
5	1000	23	4400
10	2000	27	5000
16	3000	30	6300



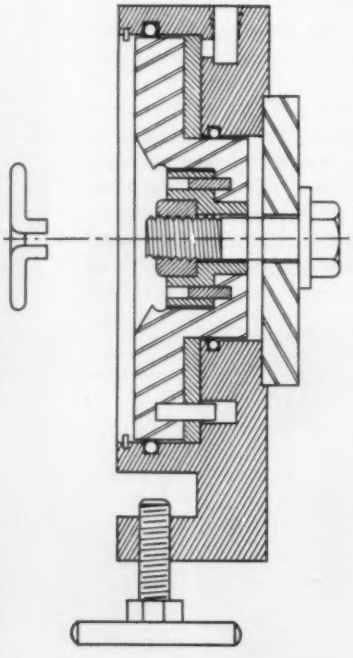


Fig. 2—Typical commercial hydraulic bolt-tension calibrator produced by Skidmore-Wilhelm Mfg. Co. When a bolt is tightened in this unit, induced tension is shown directly on the specially calibrated hydraulic gage. Data included in this article were accumulated from tests run on Skidmore-Wilhelm impact wrench and tensile testing calibrators.

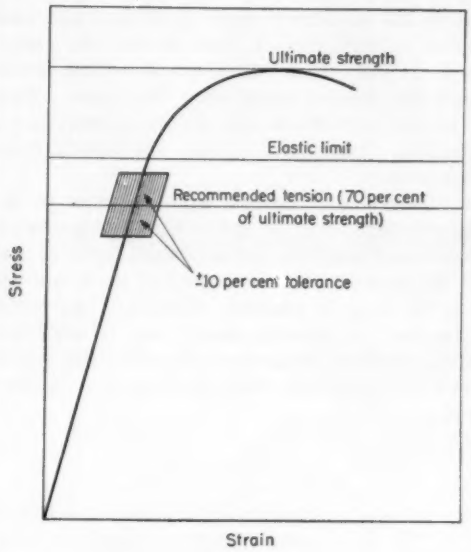


Fig. 3—Basic stress-strain relationship for bolts showing recommended area of bolt tension developed by tightening in assembly.

From Table 3, ultimate strength of this bolt is 6290 lb. Recommended initial tension is 0.70 (6290) = 4403 lb. From Table 2, the corresponding torque is 23 lb-ft. This value is the torque standard for this application.

If other washers and nuts had been used, this torque-tension relationship would have been considerably different. Table 1 gives corresponding critical points for other combinations. These data clearly point out the need for analyzing each specific combination rather than using an arbitrary estimate for setting torque standards.

Type of lubricant used on the bolt threads seems to have little effect on torque-tension relationship. The reason is probably because pressures built up between contact surfaces are so great that no ordinary lubricant is effective. However, if bolts are assembled completely dry, threads will often seize before proper tension is attained, and torque will be abnormally high without tightening the bolt properly. In some cases, the bolt may even twist off when the induced tension is as low as 50 per cent of ultimate strength.

Speed of tightening has a definite effect on the torque-tension relationship. In general, the faster the torque is applied, the lower the torque necessary to bring the bolt up to required tension.

Except in rare instances, stress induced in the

Table 3—Ultimate Strength of Standard Bolts

Nom Diam (in.)	Threads per in.	Stress Area* (sq in.)	Bolt Breaking Load‡ (lb) for material ultimate stress levels (psi) of: 55,000	60,000	65,000	70,000	80,000	90,000	110,000	120,000	130,000	150,000	170,000
No. 10	24	0.0175	960	1,050	1,140	1,220	1,400	1,570	1,920	2,100	2,270	2,620	2,970
No. 10	32	.0200	1,100	1,200	1,300	1,400	1,600	1,800	2,200	2,400	2,600	3,000	3,400
¼	20	.0318	1,750	1,910	2,070	2,230	2,540	2,860	3,500	3,820	4,130	4,770	5,410
¼	28	.0364	2,000	2,180	2,370	2,550	2,910	3,280	4,000	4,370	4,730	5,460	6,190
5/16	18	.0524	2,880	3,140	3,410	3,670	4,190	4,720	5,760	6,290	6,810	7,860	8,910
5/16	24	.0581	3,190	3,490	3,780	4,070	4,650	5,230	6,390	6,970	7,550	8,710	9,880
⅜	16	.0775	4,260	4,650	5,040	5,420	6,200	6,970	8,520	9,300	10,100	11,600	13,200
⅜	24	.0878	4,830	5,270	5,710	6,150	7,020	7,900	9,660	10,500	11,400	13,200	14,900
7/16	14	.1063	5,850	6,380	6,910	7,440	8,500	9,570	11,700	12,800	13,800	15,900	18,100
7/16	20	.1187	6,530	7,120	7,710	8,310	9,500	10,700	13,100	14,200	15,400	17,800	20,200
½	13	.1419	7,800	8,510	9,220	9,930	11,300	12,800	15,600	17,000	18,400	21,300	24,100
½	20	.1599	8,790	9,590	10,400	11,200	12,800	14,400	17,600	19,200	20,800	24,000	27,200
9/16	12	.1819	10,000	10,900	11,800	12,700	14,500	16,400	20,000	21,800	23,600	27,300	30,900
9/16	18	.2029	11,200	12,200	13,200	14,200	16,200	18,300	22,300	24,300	26,400	30,400	34,500
⅝	11	.2260	12,400	13,600	14,700	15,800	18,100	20,300	24,900	27,100	29,400	33,900	38,400
⅝	18	.2559	14,100	15,300	16,600	17,900	20,500	23,000	28,100	30,700	33,300	38,400	43,500
¾	10	.3344	18,400	20,100	21,700	23,400	26,700	30,100	36,800	40,100	43,500	50,200	56,800
¾	16	.3729	20,500	22,400	24,200	26,100	29,800	33,600	41,000	44,700	48,500	55,900	63,400
⅞	9	.4617	25,400	27,700	30,000	32,300	36,900	41,600	50,800	55,400	60,000	69,300	78,500
⅞	14	.5095	28,000	30,600	33,100	35,700	40,800	45,800	56,000	61,100	66,200	76,400	86,600
1	8	.6057	33,300	36,300	39,400	42,400	48,500	54,500	66,600	72,700	78,700	90,800	103,000
1	14	.6799	37,400	40,800	44,200	47,600	54,400	61,200	74,800	81,600	88,400	102,000	115,600
1⅛	7	.7632	42,000	45,800	49,600	53,400	61,100	68,700	84,000	91,600	99,200	114,500	129,700
1⅛	12	.8557	47,100	51,300	55,600	59,900	68,500	77,000	94,100	102,700	111,200	128,400	145,500
1¼	7	0.9691	53,300	58,100	63,000	67,800	77,500	87,200	106,600	116,300	126,000	145,400	164,700
1¼	12	1.0729	59,000	64,400	69,700	75,100	85,800	96,600	118,000	128,700	139,500	160,900	182,400
Representative Materials:			Low-carbon steel, naval bronze	Aluminum (2024-T4)	Cold-rolled low-carbon steel	Yellow brass	Medium carbon steel, low-silicon bronze, Monel	Medium-carbon steel, Type 304 stainless	Heat-treated medium-carbon steel		Heat-treated alloy steel		

*Area of circle in which diameter is mean between root and pitch diameters. This area closely approximates actual stress condition.

‡Since bolts are manufactured in many different grades, loads for other ultimate stress levels not listed may be required. Intermediate values may be interpolated.

bolt by tightening at assembly is the highest stress which will ever occur in the bolt.

Practical Example: On a tractor application, four ½-in. bolts with 13 threads per in. hold a bracket on a tool rig. Maximum load on the bracket is 16,000 lb, putting a service load of 4000 lb on each bolt. Ultimate strength of these particular bolts is 17,000 lb per bolt.

Assembling the bracket and tightening the bolts so that initial tension is low, say only 2000 lb per bolt, means that the load on each bolt will vary from 2000 to 4000 lb as the machine is used. Each time the higher load is applied there will be an elongation in the bolts and a movement in the bracket away from the tractor frame. This will result in noise, wear, and eventual loosening of the bolts.

If the bolts are tightened to 70 per cent of ultimate strength (11,900 lb), this tension wil be constant as the machine is used. Bolt load will never increase unless external loads exceed the preload figure. It will take a load in excess of bolt tension to pull the bracket away from the frame. There can be no increase in bolt stress without a corresponding elongation. Hence, the safety factor is still present.

In this example, the bracket is assumed to be a rigid member. With an elastic member, the service load would be additive to the preload. But in practical design work, it is rare to find an actual case where the load is additive. Certainly any spring lock washer or ordinary gasket may be considered as rigid members, since they are pulled flat and become effectively solid when the bolts are tightened as recommended.

Tips and Techniques

Lubricating Straightedge

Pulleys of a straightedge may be lubricated by adding a pinch of powdered graphite (from pencil sharpeners) into the ball bearings. Squeaking is eliminated, cords last longer, and the straightedge slides over the board much easier. The bearing bracket is removed and graphite placed directly in the ball bearing opening.—EDWARD J. KICK, *Columbus-McKinnon Chain Corp., Tonawanda, N. Y.*

Resultant on Slide Rule

Trigonometric scales on the slide rule can be used to find the resultant of two forces acting at right angles to each other, and the angles of the force triangle can be obtained with two settings of the slide rule and one movement of the indicator. The basic equation involved is

$$R = \sqrt{A^2 + B^2}$$

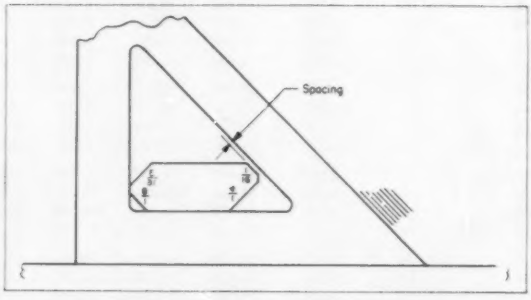
The operation is performed as follows:

1. Set index of slide opposite A on D scale. Move hairline to B on D scale.
2. Read angle at hairline on T scale. This is the angle between A and R. Angle between B and R can be found in the red figures on T scale.
3. Move slide so that angle between A and R, found in Step 2, appears under hairline on S scale. Read R at index of slide on D scale.

This method yields accurate results in a minimum number of steps as long as the ratio of A/B does not equal or exceed 10. When this ratio exceeds 10, the angles can be obtained as outlined, by reading the ST scale. The value of R is slightly greater than A. For problems in which slide-rule accuracy is acceptable, R can be taken as equal to A when A/B exceeds 10.—C. A. MARMELSTEIN JR., *civil engineer, Patchen and Zimmerman Engineers, Atlanta, Ga.*

Spacing Section Lines

Making uniform cross hatching is simplified by a spacer made from wood, plastic, heavy cardboard or other suitable material. To make it more convenient to use, the length and width should be as large as the opening in the triangle will permit. It is better to use a triangle with a relatively large opening. The spacer thickness should be greater than that of the triangle so that the finger



reliefs in the triangle will not interfere with use of the spacer. As shown, the spacer can take care of four different spacings by making the 45 deg chamfers to suit the desired spacings. In addition to making uniform cross hatching, the spacer is faster than trying to space by sight.—F. MURRAY, *Chicago, Ill.*

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Chemical Milling of Magnesium

By HUGH H. MULLER
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Los Angeles, Calif.

CHEMICAL milling is a process used to shape metals and alloys to an exact tolerance by chemical removal of metal or deep etching of parts, rather than by conventional mechanical milling or machining. Amount of metal removed, or depth of cut, is controlled by the time of immersion in the milling solution. Location of milled areas on a part is controlled by masking or protecting certain portions of the part from the milling solution. The finished part is, in many cases, directly comparable to and competitive with machine-milled parts.

Metal Preparation: The following steps are necessary to prepare magnesium for the chemical milling process:

1. Thorough cleaning is necessary to insure uniform adhesion of the maskant and uniform chemical dissolution of the metal. Special care is required when cleaning formed or forged parts to remove lubricants used in these forming operations. The standard cleaning cycle is: Solvent wipe or vapor degrease, hot alkaline cleaner, rinse, and dry.
2. Clean, dry parts are either dip, spray, or roller-coat masked, depending on size of the part. After a sufficient number of coats has been applied, parts are either oven cured for 1 hr or allowed to air cure for several hours. Patterns are located on the masked and cured part by placing a template on the part. The template is then removed and the desired sections of maskant are stripped from the part leaving those areas that are to be milled exposed to the etching solution.
3. Prepared parts are milled by immersion in a suitable etchant solution. Depth of etch is controlled by controlling the time of immersion in the solution, the rate of etch having been previously determined. Parts are rotated during the etching cycle to insure uniform etching and fillet radii. Rinsing completes the etch cycle.
4. Mask removal is accomplished by hand stripping or by immersing the part in a suitable liquid demask. Following immersion, the mask is removed with an air-water pressure rinse. The part is then dried.

Virtually all of the commercially available alloys of magnesium have been chemically milled with some degree of success, the primary difference between alloys being the resulting surface smoothness. For example, HK31 gives a very good surface. HM21, ZK60A, and AZ31 are three other alloys that have been successfully processed in quantity, although the surfaces of these alloys are not quite as smooth as the HK31.

Results of Chemical Milling: Success of the chemical milling process depends on several desirable results:

1. Physical properties of magnesium alloys do not appear to be impaired as a result of chemical milling. They are approximately those of standard machine-milled parts.
2. Metallographic examination of chemically milled surfaces shows no evidence of intergranular attack and no change in surface composition.
3. Chemical milling does not affect corrosion resistance of the metal. A protective coating such as Dow No. 1 or Dow No. 7 should be applied to the chemically milled surface to prevent corrosion.
4. The etchant reacts uniformly over the entire exposed surface resulting in an evenly milled part with a smooth etched finish, regardless of the shape of the part.
5. Parts produced by chemical milling require no further finishing operation such as sanding or polishing. Surface finish of magnesium parts varies from 20 to 140 mu-in. rms depending on the particular alloy etched. AZ31, for example, averages 120 mu-in. rms, whereas HK31 averages 35 mu-in. rms.

Advantages of Chemical Milling: Designers are not limited to machine practicality. This is the most important advantage of chemical milling. A new concept or approach to designing parts is not only possible, but mandatory to obtain maximum benefits from the process.

The most widespread use of chemical milling as applied to magnesium is in the substitution of

the process for spot welding and metal bonding to produce lightweight, integrally stiffened parts. Chemical milling eliminates many manufacturing steps and movement of parts to assembly points. Number of parts rejected is lowered as a result of making fewer parts in fewer operations. Engineering manhours are also reduced since less detail drafting is needed.

Design of sandwich construction parts can be improved by leaving heavy bands or stiffeners (integral with one skin) at attach points and chemically milling on both sides simultaneously. In so doing, the part is processed twice as fast and warpage which might result from release of stress is minimized.

Tapering of sheets, extrusions, or formed sections may be readily accomplished by chemical milling. Various depths of cut may be made on one part by progressively unmasking portions of the part during etching. Production capacity is increased since more parts can be milled in one tank than on several machines.

Closer tolerances are possible with chemical milling than with machine milling. This is especially true when considering lighter gages of sheet stock. Table 1 illustrates the overweight penalty due to tolerance on some fuselage skins.

Table 1—Weight Increase of Various Fuselage Skins With Tolerance

Tolerance (in.)	Magnesium (lb)	Aluminum (lb)	Titanium (lb)	Steel (lb)
−0.000 to +0.005	8.0	11.5	19.5	32.3
−0.000 to +0.010	16.1	23.0	39.0	64.5
−0.000 to +0.015	24.1	34.5	58.5	96.8

There are many ways to save weight by chemical milling. Extrusions, forgings, formed sections, or deep drawn parts may be lightened considerably. Parts may be designed with very thin web sections without fear of distortion or warpage.

Process Limitations: Cuts in excess of 0.5 in. are not recommended. The radius of a fillet is approximately equal to the depth of cut. Hence, a 2-in. cut has a 2-in. radius. This represents a significant increase in weight when compared to a machined part, and the part would have to be in the etch tank for many hours. Finally, it is difficult to attach other structures because of the large radius.

Sand castings may give poor results because of high porosity of the metal. However, some magnesium castings can be improved by chemical milling. For example, EZ33AT-5, HK31A-T6, AZ91C-T6, and EK41A-T6 have been chemically milled with good results. In some cases surface smoothness is greatly improved by chemical milling.

Welded assemblies require special handling because of the difference in the rate of attack between the weld area and the nonwelded area.

Surface irregularities such as dents, scratches, surface waviness, and thickness variations are reproduced but not enlarged injuriously. A part, however, that is sufficiently scratched to be rejectable before chemical milling will probably be rejectable after chemical milling.

From a paper entitled "Greater Scope to Designers and Engineers Offered by Chemical Milling of Magnesium," presented at the Magnesium Association Meeting in New York, October, 1957.

Effect of Stresses on Hardness

By S. K. SETTY, University College of Engineering, Bangalore, India
J. T. LAPSLEY, and E. G. THOMSEN, University of California, Berkeley, Calif.

SINCE hardness measurements have come into widespread use for predicting mechanical properties of heat-treated steels, it is important to understand errors that may be introduced by residual stresses, or by stresses due to external loading.

Penetration hardness tests of the Brinell and Rockwell type give hardness numbers in terms of resistance to local plastic penetration into the test piece, of a ball or cone at constant load. Hardness numbers, therefore, must be related to that state of stress induced in the test piece under the indentor which will be just sufficient to prevent continued penetration. Hence this region of metal must be at or near the instantaneous yield condition, and any simultaneously superimposed stresses could have the effect of either increasing or retarding yielding at this point.

Determination of the state of stress under the indentor which will fulfill the yield condition should reveal whether or not superimposed stresses will influence hardness readings.

A recent investigation to determine hardness under uniform stress and bending stress, and during states of stress below and at the instantaneous yield condition of the metal resulted in the following conclusions:

1. Penetration hardnesses in annealed mild steel decrease substantially in the presence of uniform tensile stresses, Fig. 1. The greatest decrease in hardness occurs when tensile stress is at the yield point of the steel.
2. Hardness of annealed commer-

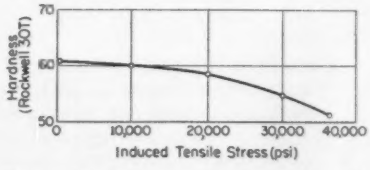

Fig. 1—Hardness curve for annealed mild steel under uniform tensile stress. As tensile stress increases, hardness decreases approximately linearly in the elastic region and departs from linearity as yield strength of the material is approached.

cially pure aluminum appears to increase only slightly when subjected to biaxial compressive stresses of a magnitude near the yield-point stress of the aluminum.

3. Induced bending stresses in annealed mild steel, when tested in such a way that the specimens had zero curvature, showed that hardness on the tension side dropped more than it increased on the compression side.
4. Scleroscope hardnesses are not affected when annealed mild steel is subjected to tensile stresses of yield point value.

From a paper entitled, "Stresses Alter Hardness," presented at the ASME Annual Meeting in New York, December, 1957.

Some uses of

Photography in Engineering

By W. C. FOULKE
Design Engineer
Eastman Kodak Co.
Rochester, N. Y.

PHOTOGRAPHS can be used successfully to reduce costs in almost all phases of engineering projects. Accuracy of the photos conveys design information which in turn clarifies instructions to draftsmen and project personnel.

Basic forms of a photograph useful for engineering work include the marked print and the unmarked print with a translucent overlay. Instructions are relayed by marking changes on prints. If extensive changes are to be shown, a clear presentation can be made by attaching a marked translucent overlay to the print. This permits inspection of both the unmarked photograph and the changes. Photographs eliminate written specifications in some cases and require less engineering time to prepare.

Application: When it is required to duplicate an existing equipment arrangement, or relocate existing equipment to sites for which complete drawings are not available, photographs can be made for transmitting information to engineering and drafting groups. When operating conditions make sketching at an installation site impossible or impractical, freehand isometric sketches to emphasize particulars can be made from photographs of the installation.

Assembly techniques may be presented effectively by making a freehand isometric sketch of the assembled unit in the center of a sheet of drawing paper. Photographs of component parts may then be pasted around the sketch. Arrows between pictures and sketch are used to indicate proper assembly sequence.

Drafting time can also be reduced greatly by substituting photographs for drawings. Also, complete drawings can be made from photographs of a scale model by taking pictures in elevation of the model, transferring them to sensitized tracing cloth, and dimensioning the reproduction.

Filed photographs and photodrawings of parts often suggest ideas which can be incorporated into current designs.

From a paper entitled "Some Uses of Photography in Engineering," presented at the ASME Annual Meeting in New York, December, 1957.

Recommended design practices for

Thin-Wall Magnesium Castings

By L. H. McCREERY
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Chance Vought Aircraft Inc.
Bridgeport, Conn.

A TREND toward thin-wall, lightweight magnesium castings which have a high strength-to-weight ratio and require little or no machining has resulted in the specifying of dimensional tolerances of 1/64 in. or less, draft angles of 0 to 1 degree, and wall thicknesses of 0.1 in. or less for cast components.

However, dimensions resulting from these specifications are not achieved without extremely accurate pattern equipment, close control of alloy and mold compositions, and special degassing techniques. When difficulties associated with these requirements are overcome, resultant thin-wall castings show improved mechanical properties.

The following factors regarding casting drawing practices are considered important toward achieving thin-wall castings:

1. The drawing should show, as completely as possible, the widest limits of acceptability which can be tolerated. Anything more precise raises the price of the cast product.
2. A central locating point for dimensioning, checking, and machining saves castings which, if machine cuts had been located from exterior surfaces, would have been scrapped. It also eliminates confusion and simplifies discussion regarding drawings or castings.
3. Avoid build-up of metal thickness where various sections are joined which results in inferior metal quality and mechanical properties.
4. Close tolerances are best applied to external surfaces and not across parting lines, nor dimensioned from cored areas.
5. Indicate the widest dimensional variation that can be tolerated

from piece to piece.

6. Use development tolerances where possible. This may avoid expensive pattern changes since certain noncritical dimensions can be allowed to vary to accommodate slight inaccuracies in allowances made in the pattern dimension for solidification and thermal shrinkage, with the desired dimensional tolerance being applied to the developed dimension.
7. Use a maximum casting weight for weight control where possible, rather than close tolerances on wall thicknesses. This involves showing an absolute minimum dimension to insure structural adequacy.
8. Avoid heat treatment if strength requirements can be met otherwise, since heat treatment often results in distortion with subsequent expensive straightening required.

From a paper entitled "Magnesium Precision Castings Open New Production Potential," presented at the Magnesium Association Meeting in New York, October, 1957.

Fretting-Fatigue Damage

of titanium and steel

By W. L. STARKEY, S. M. MARCO, and J. A. COLLINS
Department of Mechanical Engineering
Ohio State University
Columbus, Ohio

PRIMARY detrimental effects of fretting on machine parts are: Corrosive surface damage due to fretting corrosion; loss of fit due to fretting wear; and fatigue failure due to fretting fatigue.

Fretting may be defined as that mechanical action whereby the originally contacting surfaces of two solid bodies are pressed together by a normal force and are caused to undergo cyclic relative sliding motion, but where the magnitude of the normal force is great enough and the amplitude of the cyclic motion is small enough to effect a significant restriction to the flow of any fretting debris away from its point of origin.

Tests were conducted recently to obtain a quantitative evolution of fatigue damage caused by fretting titanium against steel. Effects of shot peening and cold rolling as fretting fatigue inhibitors were evaluated. Results of the investigation are discussed in terms of the probable basic mechanisms of fretting and fatigue phenomena and effects of prior cold working on these phenomena.

Results indicate that fretting treatments applied to both steel and titanium specimens cause a progressively greater reduction in fatigue resistance as fretting treatment is made more severe. Further, application of a shot-peening or cold-rolling treatment prior to the fretting treatment results in a very significant improvement in fretting-fatigue resistance.

Comparing steel with titanium, it may be noted that although both polished steel specimens and polished titanium specimens exhibit a significant decrease in fatigue resistance with increased fretting severity, titanium is much more sensitive to fretting fatigue than steel. Fretting-fatigue resistance of polished titanium specimens is substantially improved by the shot-peening or cold-rolling treatment.

Regardless of the particular combination of active fretting mechanisms, the result of fretting fatigue is the formation of a system of stress raisers which are conducive to the initiation and propagation of fatigue cracks. If the stress field is sufficiently unfavorable, the fatigue crack continues to propagate and fatigue fracture ultimately results.

Cold working results in the formation of a skin layer of residual compressive stresses due to local plastic deformation. Thus, under the conditions of an applied cyclic stress field, compressive skin stresses effectively reduce the cyclic tensile peak stresses in the region of the surface. This results in retardation or complete arrest of the fatigue-crack growth depending on relative magnitudes of applied stress, residual stress, and local stress concentration.

In all cases of shot peening and cold rolling, a layer of surface compressive stresses was formed. Depth and intensity of the compressive layer was different for different cold-working treatments. Subsequent fretting treatments resulted in the formation of stress raisers due to the fretting phenomena, and fatigue cracks were initiated. Under the conditions of mild and severe shot peening and severe cold rolling, the compressive skin stress field did not permit rapid crack propagation and consequently the endurance limit of the fretted specimens under these conditions is the same as specimens subjected to no fretting at all. In the case of mildly cold-rolled specimens, compressive surface stresses were apparently responsible for a definite mitigation of fretting damage but were not of sufficient benefit to eliminate damage by arresting crack growth.

Trapping of fretting debris is an important factor in the later stages of fretting. Since most oxides reflect a substantial increase in volume compared to the parent metal, oxide debris may result in high local pressures if trapped. These high pressures tend to accelerate the formation and propagation of fatigue cracks leading to fretting fatigue failure. Any means of preventing formation of debris or removing debris as it is formed also should aid in the mitigation of fretting fatigue.

From a paper entitled "The Effect of Fretting on Fatigue Characteristics of Titanium-Steel and Steel-Steel Joints," presented at the ASME Annual Meeting in New York, December, 1957.

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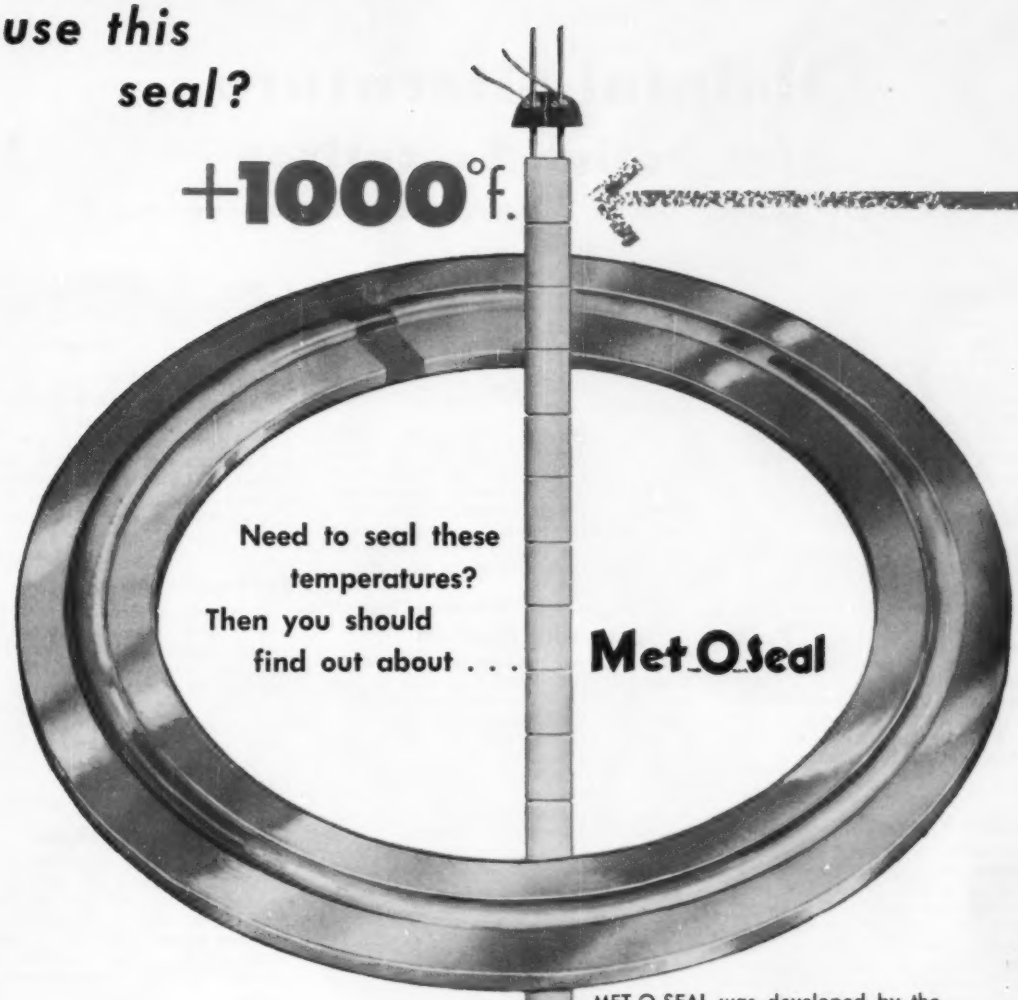

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Pillow blocks, flange blocks, and ball bearings are described in detail in illustrated catalog and Price Sheet BU-101-A. The blocks use malleable housings and contain self-aligning ball bearing units, lubricated for life and permanently sealed. Two heights and 28 sizes are offered. 12 pages. Browning Mfg. Co., Maysville, Ky. G

Circle 551 on Page 19

Instrument Components

Extensive line of precision instrument parts and components for use in research, prototypes, production, and test fixtures is available from listings in illustrated Catalog 12. Specifications of all parts are included. Gears, shafts, dials, cams, speed reducers, bearings, differentials, gearboxes and universal joints are among many parts covered. 128 pages. PIC Design Corp., 477 Atlantic Ave., East Rockaway, L. I., N. Y. D

Circle 552 on Page 19

Plastic Gate Valve

Varied corrosive, slurry, and vacuum services are applications for the Flex-Plug all plastic gate valve, subject of illustrated Catalog 42.0. Drawings show its straight-through, no-pressure-drop feature. Specifications of the ½ to 2-in. size unit are given. 4 pages. Vanton Pump & Equipment Corp., 201 Sweetland Ave., Hillside, N. J. D

Circle 553 on Page 19

Drives & Motors

"Sky High to Ocean Blue" is a well-illustrated Booklet A-2400 which describes specialized drives and motors built to demanding industrial and government specifications. Covered are integral ac motors to 400 hp, dc units to 1000 hp, dc and ac generators and motor-generator sets, gear-motors, and variable speed drive systems and controls. 12 pages. Reliance Electric & Engineering Co., 24701 Euclid Ave., Cleveland 17, Ohio. F

Circle 554 on Page 19

Ferrous & Nonferrous Castings

Of particular interest in new folder on B-Mold ferrous and nonferrous castings is a comparative description of advantages of investment, permanent mold, and centrifugal castings. It stresses correct selection of casting method. 4 pages. Buckeye Brass & Mfg. Co., B-Mold Div., 203-213 Central Ave., Mansfield, Ohio. G

Circle 555 on Page 19

Rotary Air Pumps

Detailed blueprints in booklet show actual installations of Leiman rotary air pumps used for vacuum and pressure operations, including lifting, blowing, suction, extraction, testing, and drying. 24 pages. Leiman Bros., Inc., 102 Christie St., Newark 5, N. J. D

Circle 556 on Page 19

Voltmeter

Self-contained phase-angle voltmeter for laboratory, production, and field use is described and illustrated in Series 200 Bulletin. Operating principles, range, accuracy, and other features are detailed. Applications are given. 2 pages. North Atlantic Industries, Inc., 603 Main St., Westbury, L. I., N. Y. D

Circle 557 on Page 19

Designing with Aluminum

Twenty-four phases of aluminum designing techniques and aids to design engineers are covered in illustrated booklet "Designing with Aluminum." Properties of various alloys; best application for standard fabricating forms; and techniques for forming, fastening, welding, and finishing are among subjects. 56 pages. Kaiser Aluminum & Chemical Sales, Inc., 919 N. Michigan Ave., Chicago 11, Ill. M

Circle 558 on Page 19

Industrial Fasteners

Engineering data on line of special industrial fasteners included in condensed catalog cover dimensional drawings, specifications, and features. Link-Lock, Hinge-Lock, Spring-Lock, Quick-Lock, Roto-Lock, and Dual-Lock are types covered. 8 pages. Simmons Fastener Corp., N. Broadway, Albany 1, N. Y. D

Circle 559 on Page 19

Shaft Couplings

Applications for full-floating shaft couplings are outlined in illustrated Bulletin 98. Details of the units used to connect shafts that are spaced far apart are included. 4 pages. Thomas Flexible Coupling Co., Warren, Pa. F

Circle 560 on Page 19

High Temperature Alloys

Properties of Haynes alloy No. 25 and Hastelloy alloy X are presented in two booklets. Former is a wrought cobalt base alloy for jet engine use and latter is a nickel base alloy offered in wrought and cast forms. Technical data are included in both. 28 pages each. Haynes Stellite Co., 30-20 Thomson Ave., Long Island City 1, N. Y. C

Circle 561 on Page 19

Silicone Compounds

Properties and uses of 520 Series of silicone compounds are described in data sheet SF-1010A. They are argano-silicone polymers with good lubricating and solubility properties. 8 pages. Union Carbide Corp., Silicones Div., 30 E. 42nd St., New York 17, N. Y. C

Circle 562 on Page 19

Ratchet Wrenches

Reversible ratchet wrenches, Warnock and Simplex strap wrenches, and Swaco car movers and hopper car wrenches are described and illustrated in Catalog 61. Specifications of each product are given. 8 pages. Lowell Wrench Co., Worcester, Mass. B

Circle 563 on Page 19

Self-Tapping Inserts

H Series of Tap-Lok self-tapping inserts with Class 3B internal threads permit application of standard threaded fasteners to soft metals without danger of stripping. Specifications and aircraft application data are included in 4-page folder and 2-page data sheet. Groov-Pin Corp., 1125 Hendricks Causeway, Ridgefield, N. J. D

Circle 564 on Page 19

Low Voltage Switchgear

Operating and maintenance innovations in K Line low voltage power switchgear and circuit breakers are featured in illustrated Bulletin 6004-C. Ratings range from 225 to 4000 amp. Application tables provide ratings, control power requirements, and ranges of overcurrent trip devices. 20 pages. I-T-E Circuit Breaker Co., Switchgear Div., 19th & Hamilton Sts., Philadelphia 30, Pa. C

Circle 565 on Page 19

Adhesives

Synopsis of Epibond adhesives which serve as bonding agents for metals, plastics, rubber, and ceramics is found on form. Properties of five products are briefly outlined. 1 page. Furane Plastics Inc., 4516 Brazil St., Los Angeles 39, Calif. L

Circle 566 on Page 19

Epoxy Casting Resin

Maraset resin No. 341, a lead-filled epoxy casting material, is subject of data sheet. It is useful in making radioactivity-shielding containers and structures. Properties are summarized. 1 page. Marblette Corp., 37-31 30th St., Long Island City 1, N. Y. D

Circle 567 on Page 19

Electric Plug Selection

"How To Select a Cannon Plug" is an illustrated guide to electric plugs. It contains a check list which considers size, number and style of contacts, mounting space, coupling methods, insulation, and environmental conditions. Representative connectors are shown and application data are given. 40 pages. Cannon

as NEW *as* TOMORROW...

VALVAIR plug-in valves cut assembly and maintenance costs!

Model PA-121

Built-in plugs and connectors in Valvair's new ¼ in. Speed King 4-way control valves complete electrical circuits *automatically* . . . reduce assembly and maintenance time to a cost-cutting minimum! Permanent electrical connections are made in manifold or sub-base at assembly . . . then valves and pilots are plugged in . . . bolted down. There's no need to disturb equipment wiring for quick in-service maintenance!

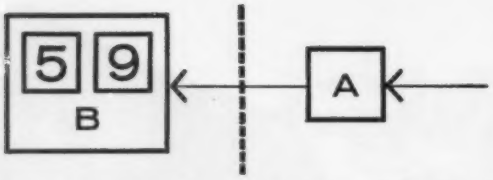
Navy M bronze and stainless steel components assure 20 million cycle-plus dependability. Interchangeable pilot, with coil guaranteed against burn-out for life of valve, fits any plug-in Speed King. Coils for ac or dc, any voltage . . . 35—200 psi range . . . optional manual over-ride . . . ¼ in. cylinder ports . . . 2 or 3 station manifold with common inlet, exhaust and conduit ports, or sub-base mounted . . . valve meets JIC standards!

Whether you build or operate machines, you'll find that Valvair plug-in control valves set new standards of adaptability, performance and economy! Valvair Corp., 454 Morgan Ave., Akron, Ohio.

AA-6889

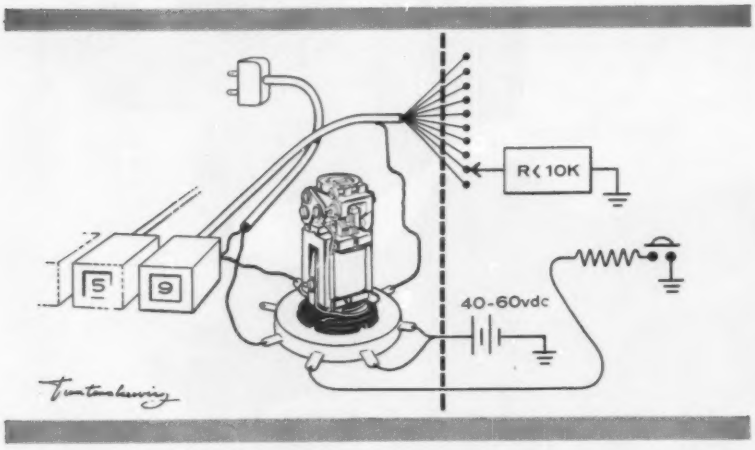
RESEARCH...
PROGRESS...
LEADERSHIP...

Representatives in principal cities.



fast switch ON THE NUMBERS

Taking coded information, translating it into decimal form (A) and displaying it on the wall (B) seems to be a matter of concern to a fair number of people these days. Part "B"—making the right number come up—offers an opportunity to demonstrate the virtues of a Sigma Series 72 polar relay. As explained below, halting of display devices can be accomplished in a variety of ways. But because of the 72's combination of high speed, precision and sensitivity, the problem of consistently keeping up with a high speed number drive on very little signal power is solved all at once.



The breadboard diagram to the left of the dashed line has been drawn by our artist, who feels that schematic symbols can never do justice to a Sigma Type 72AOZ-1000-TS High Speed Polar Relay. Of course this may be an expensive way to run a cycledec, but if you are in a hurry you don't want to have to dish up nine separate pulses from the info department (right of the dashed line). Besides, what if it missed counting one of them? To be sure, the relay could be eliminated and the cycledec run directly through its own internal switch contacts. But then AC supply voltage would have to be put on all switch points except the designated one. This would make it rough for any little solid state peanut you tried to put in that box marked R< 10K.

As it is, the 72 will remove the supply from the cycledec .0005 seconds after it lands on the right number, and restore the supply .0008 seconds after you move the ground to another switch point and "push" the reset button. Incidentally, completion of selection puts power on the other contact of the 72, which can then run lights, bells or some other success signal.

Some of the virtues of a Type 72AOZ-1000-TS TCP* SPDT polar relay are:

Contacts rated 500,000,000 operations 60 ma. 120VDC

Coils, two, 1000 ohms each

Either-side stable, operate 0.56 ma. either way either coil

**Armature tungsten, fixed contacts copper-palladium*

You can get one such 72 relay with removable dust cover for $30.00, or for less money in quantity. Samples are available on order, or a bulletin simply on request.

SIGMA INSTRUMENTS, INC.

89 Pearl Street, So. Braintree 85, Mass.

Circle 469 on Page 19

Helpful Literature

Electric Co., 3208 Humboldt St., Los Angeles 31, Calif. L

Circle 568 on Page 19

Motor Drives

Details of corrosionproof variable speed Motodrives are presented in illustrated Bulletin M-578. Close-grooving lubrication eliminates sticking discs in corrosive atmospheres. 4 pages. Reeves Pulley Co., Columbus, Ind. J

Circle 569 on Page 19

Custom Moldings

Design, compounding, laboratory work, and mold storage services available to the buyer of specialized molded rubber parts are outlined in illustrated folder. Facilities for producing parts of Vix-Syn synthetic rubber are covered. Typical parts are shown. 4 pages. E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa. C

Circle 570 on Page 19

Instrument & Control Switches

Available as either maintained or spring return contact types, Type 210 instrument and control switches are used in conjunction with circuit breakers, transformer tap changers, and motor-operated rheostats. The 20-amp switches are described in Bulletin 14B8112A. 8 pages. Allis-Chalmers Mfg. Co., Milwaukee 1, Wis. K

Circle 571 on Page 19

Stress-Rupture & Creep Tests

Speedomax H 2-Action D.A.T. control which holds specimen temperatures within ±1° F for stress-rupture and creep testing is described in Data Sheet 274(1). Auxiliary equipment is listed and illustrated. 2 pages. Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa. E

Circle 572 on Page 19

Pinch-Type Valves

Pinch-type rubber-body valves which feature straight through flow, bubble-tight closure, and abrasive and corrosion resistance are subject of Catalog 857. Valves are made in ¼ to 14 in. sizes for pressures to 200 psi and deliveries to 29,000 gpm. 16 pages. RKL Valve & Mfg. Co., Rt. 38 & Rudderow Ave., Maple Shade, N. J. D

Circle 573 on Page 19

Wire Markers

Wires from miniature type to large cables and harnesses can be identified with self-adhering Vari-temp cloth and aluminum-foil markers described in brochure. They are fungus and high temperature resistant. 12 pages. Western Lithograph Co., Westline Products Div., 665 E. Second St., Los Angeles 54, Calif. L

Circle 574 on Page 19

Testing Equipment

"From Idea to Production" is title of bulletin explaining special mechanical, electronic, and hydraulic engineering and manufacturing facilities of this company. Firm builds test units for automatic pilot mechanisms and other precision equipment, as well as complex machines. 4 pages.

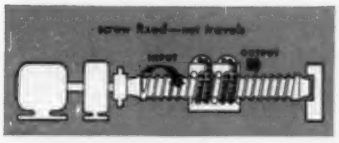
SAGINAW b/b SCREWS

Put "Muscle" into Linear Motion

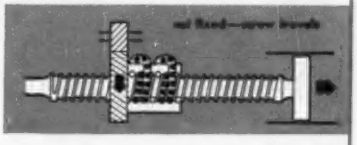
Saginaw b/b Custom-Ground Screws dependably actuate—with minimum power, weight and space—the flaps and speed brakes on latest airplanes.

HOW and WHY SAGINAW b/b SCREWS

Actuate and Position with Over 90% Efficiency...4/5 Less Torque



Nut glides on steel balls. Like stripes on a barber pole, the balls travel toward end of nut through spiral "tunnel" formed by concave threads in both screw and mating nut.



At end of trip, one or more tubular guides lead balls diagonally back across outside of nut to starting point, forming closed circuit through which balls recirculate.

1 POWER SAVINGS. Operating with over 90% efficiency, Saginaw b/b Screws permit much smaller motors with far less drain on electrical systems, and also simplify circuitry.

2 SPACE SAVINGS. Saginaw b/b Screws themselves are compact. They permit smaller motors and gear boxes and eliminate auxiliary equipment required by hydraulics.

3 DEPENDABLE PERFORMANCE. Saginaw b/b Screws are far more reliable than hydraulics or pneumatics. Gothic-arch grooves, yoke deflectors and multiple circuits provide added assurance.

4 PRECISE POSITIONING. Saginaw b/b Screws will position components far more precisely than hydraulics or pneumatics; tolerances on position are held within .0006 in./ft. of travel.

5 TEMPERATURE TOLERANCE. Normal operating temperature for Saginaw b/b Screws is from—75°F. to +275°F. But in selected materials, they will function efficiently at temperatures as high as +900°F.

6 LUBRICATION. If lubrication fails the Saginaw b/b Screw will still function with remarkable efficiency. Units have been built and qualified for operation without lubrication.

JUST ONE OF MANY APPLICATIONS

Because they actuate more efficiently . . . economically . . . dependably than Acme screws, hydraulics or other actuating devices, Saginaw b/b Screws are being specified more and more by progressive manufacturers. Already they have been applied to machine tools, jet engine afterburners, guidance mechanisms, nuclear reactor controls, electronic control equipment—plus a host of other applications. They've been operationally proved... and they're backed by all the research and test facilities of the General Motors Technical Center.

SOLVE YOUR ACTUATION PROBLEMS

Re-examine your actuation or positioning needs in the light of better performance, efficiency and economy. If you have a critical or precision application, order custom-machined Saginaw b/b Screws. We have successfully built them from 1½ inches to 39½ feet long—⅜ inches to 10 inches diameter. (If your application requirements are not critical . . . less stringent . . . you may be able to satisfy your actuation needs by ordering from Saginaw's exclusive "off-the-shelf" stock. It's available in seven standard rolled thread sizes, cut to length, for low cost and fast delivery.) What's more, if you're not sure how best to apply Saginaw b/b Screws to your product, Saginaw's experienced engineers will gladly go to work on your problem—without obligation. Just write or phone us or fill in and mail the handy coupon below.

SEND FOR FREE 1958 ENGINEERING DATA BOOK...

or see our section in Sweet's Product Design File

Saginaw Steering Gear Division
General Motors Corporation
b/b Screw and Spline Operation
Dept. 6MD, Saginaw, Michigan

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ball bearing
Screws & Splines

SAGINAW STEERING GEAR DIV., GENERAL MOTORS CORP., SAGINAW, MICH.

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Before you specify an expensive special gauge, check your requirements with USG. Available to you are 50,000 different standard gauges. With slight modification, many of these will meet special design problems.

USG saves manufacturers thousands of dollars annually by making possible "special" gauge designs from standard components. For help with your gauge problems call or write the factory today.

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MORE THAN 50,000 TYPES OF GAUGES • SUPERGAUGES • SOLID FRONT GAUGES • RECEIVER GAUGES • TEST GAUGES • RECORDERS • CONTROLLERS • TRANSMITTERS • PSYCHROMETERS • AVIATION INSTRUMENTS

Helpful Literature

ConRay Corp., 29 W. Apple St., Dayton, Ohio. G

Circle 575 on Page 19

Compression Blower

Performance graphs and engineering data relating to the axial-flow, positive displacement CycloBlower for compression and vacuum service are provided in Bulletin CB-157. Unit's service range is 85 to 3342 cfm. 4 pages. CycloBlower Co., 132 S. Pershing Ave., York, Pa. E

Circle 576 on Page 19

Slide Assemblies

Specification sheets comprising this bulletin present drawings and dimension data on Gilman light and heavy duty slide assemblies. Two to 8-in. tracing templates are also provided. 12 pages. Russell T. Gilman, Inc., 624 Beech St., Grafton, Wis. K

Circle 577 on Page 19

Fastener Facilities

Facilities for production of cold-headed metal specialties and threaded fasteners are illustrated in brochure. Company produces carbon, alloy and stainless steel, aluminum, brass, and bronze parts for automotive, aviation, electrical, machinery, and metal fabricating industries. Quality Fasteners, Inc., Kalamazoo, Mich. H

Circle 578 on Page 19

Terminals & Connectors

Revised catalog covers time-saving solderless terminals and connectors for crimping to wire extremities. Data and sizes facilitate selection for every wiring job requirement. Electrix Terminals & Connectors, Inc., 990 E. 67th St., Cleveland 3, Ohio. G

Circle 579 on Page 19

Fire & Overheat Detectors

Brochure "Continuous Fire and Overheat Detection for Aircraft Safety" explains operating principle behind the detector, gives specifications, and discusses its uses in general industry. Detector features discrete, pinpoint sensing and has no moving parts, tubes, or transistors. 8 pages. Fenwal Inc., Pleasant Street, Ashland, Mass. B

Circle 580 on Page 19

Heat Exchanger

The Yates-American fixed bundle heat exchanger for heating and cooling liquids is described as to dimensions, flow ranges, and heat transfer rates in Bulletin HT-1A. Units are made in single, two, and four-pass constructions. 6 pages. Yates-American, Beloit, Wis. K

Circle 581 on Page 19

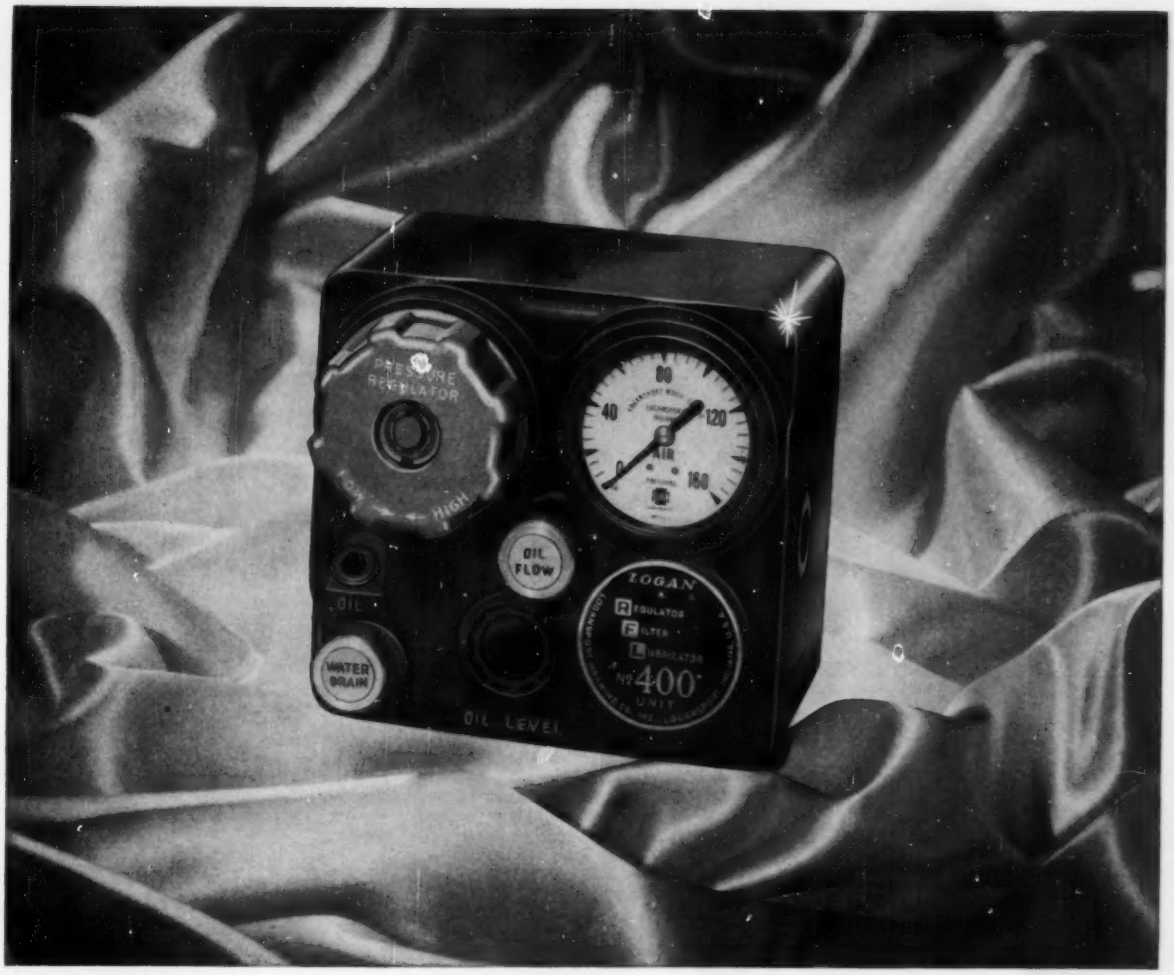
Cams

Booklet SC-1 describes service available for industry which provides special cams for practically any need. Production facilities are described. 8 pages. American Cam Co., Box 2106, Hartford, Conn. B

Circle 582 on Page 19

Vibration Mountings

Engineering specifications and performance data are given in Bulletin K4D on 15 different types of ma-



Illustrated—Logan Model 400 RFL Unit

Look to Logan

the ultimate in air circuit accessories

Logan RFL Unit, the designers choice for over a decade! Protects your air-powered equipment . . . regulates pressure . . . filters air . . . lubricates air. Adds years of dependable performance.

New Model 400, illustrated above, is a companion model to the well-known Model 600.

FREE SEND FOR THE "LOGAN CALCULATOR"

MEMBER: Natl. Mach. Tool Builders' Assn.; Natl. Fluid Power Assn.

LOGANSPORT MACHINE CO., INC.
811 CENTER AVENUE, LOGANSPORT, INDIANA

PLEASE SEND COPY OF CATALOG:

- ☐ 100-1 AIR CYLINDERS
- ☐ 100-2 MILL-TYPE AIR CYLS.
- ☐ 100-3 AIR-DRAULIC CYLS.
- ☐ 100-4 AIR VALVES
- ☐ 100-5 LOGANSQUARE CYLINDERS
- ☐ 100-5-1 ULTRAMATION CYLINDERS
- ☐ 300-2 PRESSES
- ☐ FACTS OF LIFE
- ☐ 200-1 HYD. POWER UNITS
- ☐ 200-2 ROTOCAST HYD. CYLINDERS
- ☐ 200-3 750 SERIES HYD. CYLINDERS
- ☐ 200-4 and 200-7 HYD. VALVES
- ☐ 200-6 SUPER-MATIC CYLS.
- ☐ 300-1 CHUCKS
- ☐ ABC BOOKLET
- ☐ CIRCUIT RIDER

TO:

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COMPANY _____

ADDRESS _____

Circle 472 on Page 19

Only PEM Self-Clinching Fasteners provide all these advantages:

PROVIDE load carrying threads in any sheet metal "too thin to thread".

FAST simplified Clinching—one or several at a time—with standard tools. Just squeeze and they're locked in. Speed production—save labor.

POSITIVE lock against pull-out and torque.

REVERSE side of sheet remains flush.

SIX TYPES—in steel, stainless steel, aluminum and monel—answer most industry requirements.

FIND OUT why many leading manufacturers have standardized on PEM nuts. Write for literature and samples for test. Penn Engineering & Manufacturing Corp., Doylestown, Pa.

PEM

Circle 473 on Page 19

Helpful Literature

chinery mountings which use steel springs, rubber, and cork to absorb vibration. Selector chart covers wide range of equipment. 4 pages. Korfund Co., 48-19D 32nd Place, Long Island City 1, N. Y. D

Circle 583 on Page 19

Stripped Pumps

Series S and SA stripped pumps for built-in applications are detailed in Catalog Section 106. S pumps are made in 6 sizes from 2 to 50 gpm and pressures to 100 psi; SA pumps are furnished in 1/3 to 200 gpm capacities and pressures to 200 psi. 12 pages. Tuthill Pump Co., 939 E. 95th St., Chicago 19, Ill. J

Circle 584 on Page 19

Wire Casing Tubing

Zipper type flexible tubing for encasing multi-conductor wires or cables consists of a plastic-saturated, glass fiber backing laminated to aluminum, lead, or magnetic foil. Zippertubing is available in ⅜ in. ID sizes and larger. Details are given in catalog sheet. 2 pages. Zippertubing Co., 750 S. San Pedro, Los Angeles, Calif. L

Circle 585 on Page 19

Electrical Controls

Bulletin 106 explains applications of the most common Versatrol circuits, both automatic and limit. These electrical controls are used to control thickness, torque, current, voltage, radiation, pressure, viscosity, pH, light, speed, and load. 12 pages. Assembly Products, Inc., 75 Wilson Mills Rd., Chesterland, Ohio. G

Circle 586 on Page 19

Clutches & Brakes

Over 120 configurations as well as custom-designed miniature and subminature clutches and brakes which operated electro-magnetically are detailed in illustrated catalog. Design data include cut-away drawings, schematic diagrams, performance curves, and technical information. 28 pages. Autotronics, Inc., Route 1, Box 812, Florissant, Mo. I

Circle 587 on Page 19

Airborne Hydraulic Pumps

Listed in Bulletin A-5206-B are 36 sizes of airborne, constant-displacement, piston type hydraulic pumps with theoretical flow capacities from 0.318 to 38.116 gpm at 1500 rpm. These light weight pumps are recommended for 3000-psi service at temperatures to 275° F. 4 pages. Vickers Inc., Detroit 32, Mich. H

Circle 588 on Page 19

Cam Timers

Engineering information, a gear rack selection table, and design details of a complete line of single cycle, single and multiple cam timers are presented in Bulletins 34 & 36. 4 pages. Industrial Timer Corp., 1407 McCarter Highway, Newark 4, N. J. D

Circle 589 on Page 19

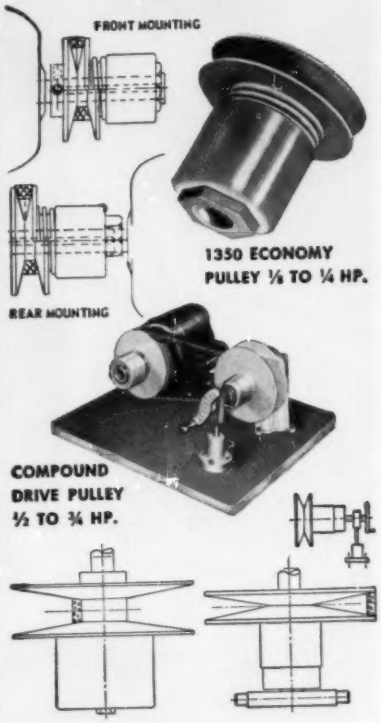
Relays

Telephone, sensitive, power, general purpose, and special purpose relays are subject of Catalog 13C083.

Lovejoy

Fractional Horsepower

VARIABLE SPEED PULLEYS



Economical—
low in initial cost . . . easily installed on old or new equipment.

Minimum Maintenance—
simple construction assures trou ble-free operation . . . lifetime lubricated with oil-impregnated bronze bushings.

Constant Belt Alignment—
inner and outer pulley sheaves open equally to provide smooth, infinitely variable speed ratios to 8 to 1.

No Slippage—
Sure grip of belt sides delivers full traction under all load conditions...result is greater horsepower carry capacity.

Get the new 12-page Lovejoy catalog! Write today.

LOVEJOY FLEXIBLE COUPLING CO.
4818 W. Lake St., Chicago 44, Ill.

Circle 474 on Page 19

ORANGE *Cage Type* NEEDLE BEARINGS

are true running in any position

VERTICAL . . . . TILTED . . . . . HORIZONTAL

Cage assures permanent alignment of rollers

Each needle roller is retained in pockets of a cage made of anti-friction, non-ferrous metal. These pockets guide and align the rollers along their entire length. The cage does not wear on the rollers, since the cage land rides on the outer race. Square end rollers provide maximum effective roller length.

The Rollers Roll evenly — never Skew or Slide

The non-skewing, aligned roller action of Orange Cage Type Needle Bearings adds many additional advantages to the high-load, small-space characteristics of conventional needle bearings.

For example: Less internal friction—quieter running—meet higher precision requirements—operate at higher speeds—may be used on overhung mountings—less affected by misaligned mountings or uneven loading—longer life expectancy.

Orange Cage Type Needle Bearings are available in stock sizes from ½" to 8" dia., interchangeable with all standard needle bearings. Write for Engineering Manual M-56.

● Kingsbury Machine Tool Corp. uses Orange Cage Type Needle Bearings to align the vertical spindles in the drill heads of Kingsbury Indexing Automatics, to meet small space and precision operating requirements.

WRITE for 40-page Engineering Manual showing construction, dimensions, capacities of all Orange Roller Bearings.

ORANGE ROLLER BEARINGS

ORANGE ROLLER BEARING CO., Inc.
556 Main Street, Orange, N. J.

Needle Bearings — Staggered Roller Bearings
Journal Roller Bearings — Thrust Roller Bearings
Cam Followers

The answer to STUD problems

LOCTITE® SEALANT

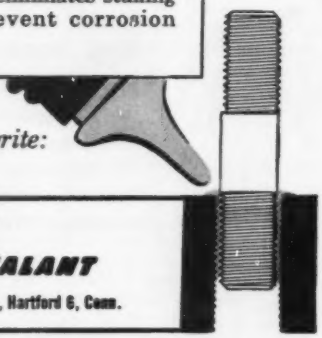
The Liquid Lock For Threaded Fasteners

No interference fits—eliminate close tolerances . . . permits Class 2 rather than Class 5 thread fit in tapped holes.

No blind hole tapping—drill clean through . . . LOCTITE seals and locks in *one* operation.

No high driving torque—eliminate broken studs . . . reduce stripped threads in magnesium and aluminum castings.

LOCTITE's locking action develops *after* stud is in place . . . locks stud securely . . . eliminates staking or stud welding . . . helps prevent corrosion between threads.

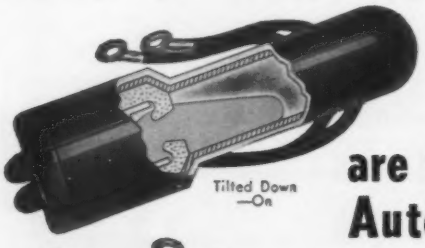


For analysis of your stud problems write:

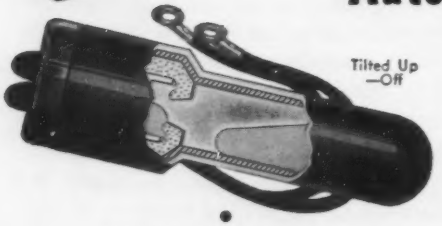
LOCTITE® SEALANT

AMERICAN SEALANTS CO. • 111 Woodbine St., Hartford 6, Conn.

Circle 476 on Page 19



DURAKOOL Tilt Switches are the Life of your Automatic Controls



MILLIONS OF CYCLES WITHOUT FALTERING

This steel-clad Durakool mercury tilt switch has unique construction features that deliver years of trouble-free performance on the most difficult assignments you can find. Operating under sealed-in, pressurized hydrogen gas, it takes 24 hours, fast cycling schedules in stride. 7 sizes, 1 to 65 amperes. Send for Bulletin 525.

See telephone directory for local distributor, or write.

DURAKOOL, INC.

ELKHART, INDIANA, U.S.A.

700 WESTON RD., TORONTO 9, CANADA

Durakool ALL-STEEL MERCURY *Switches*

Circle 477 on Page 19

Helpful Literature

General information is given on electromagnetic relay contacts, coils, enclosures, and terminals. Specs on each model are tabulated. 16 pages. Potter & Brumfield, Inc., Princeton, Ind. J

Circle 590 on Page 19

Metal Stitching

"Metal Stitching, a New Idea in Fastening" gives detailed information on stitching metal to metallic or nonmetallic materials. Cases are cited showing cost savings up to 66 per cent. A complete line of Acme Steel metal stitchers is described. 16 pages. Acme Steel Co., 135th St. & Perry Ave., Chicago 27, Ill. I

Circle 591 on Page 19

Expanded Metal & Grating

Often called the material of a thousand uses, expanded metal is detailed in Technical Bulletin 20-4. Material can be supplied in carbon and stainless steels, and aluminum, in standard and flattened mesh. 8 pages. Joseph T. Ryerson & Son, Inc., Box 8000-A, Chicago 80, Ill. I

Circle 592 on Page 19

Zinc Alloy Wing Nuts

Two new types of zinc alloy wing nuts, one with a capped threaded section and the other with a large washer base, are shown in two data sheets. Wing nuts are offered in thread sizes from No. 10 and 8, respectively, to 5/16-in., and have 1-in. wing spread. 1 page each. Gries Reproducer Corp., 400 Beechwood Ave., New Rochelle, N. Y. D

Circle 593 on Page 19

Weighing Control

The Model 219 two-level control relay is used with a weighing cell for check-weighing, sorting packages into three groups, and process control. This electronic device is detailed in Bulletin AV-9A7. 2 pages. ACF Industries Inc., Avion Div., 11 Park Place, Paramus, N. J. D

Circle 594 on Page 19

Electrical Contacts

Engineering data, selection, materials, design, and sizes of electrical contacts for practically any conceivable purpose are presented in Bulletin KCS 957. 4 pages. Contacts Inc., 1100 Silas Deane Highway, Wethersfield, Conn. B

Circle 595 on Page 19

Metal Products

Carbide and Tantung cutting tools, resistance welding electrodes, and electrical contacts are some of the products offered by this company. Various products produced for standard and special purposes are outlined in comprehensive brochure. 28 pages. Fansteel Metallurgical Corp., North Chicago, Ill. J

Circle 596 on Page 19

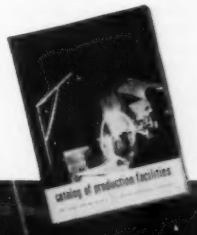
Bearing Bronzes

"Sabeco Bronze, the Jewel of Metals!" is title of booklet which depicts the facilities of this company for producing various bronze bearing alloys for specific load and service conditions. Physical characteristics and analyses are included. 12 pages. Sagi-

Extruded Shape Formed and Flash Butt-Welded . . . the Low-Cost Way to Make this 268 lb. Stainless Steel Ring

By using extruded or mill-rolled shapes and flash butt-welding, American Welding can frequently help customers slash production costs of their circular products over other methods of manufacture. Savings in expensive metals are substantial, plus sizable reduction in machining time. And where some of the more difficult metals to weld — such as titanium, aluminum, zirconium, stainless and heat-resistant alloys — are required, American Welding has the special knowledge and equipment to do those difficult jobs to your specifications.

The use of flash butt-welded rings, bands, and assemblies has saved millions of dollars for jet engine manufacturers . . . why not investigate what economies it can mean to you. If it's circular and of metal — call American Welding first!



NEW PRODUCTS CATALOG AVAILABLE. Write today for 20-page catalog illustrating the many types of circular products American Welding can form, weld and machine for you.

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THE AMERICAN WELDING & MANUFACTURING CO.
180 DIETZ ROAD • WARREN, OHIO

put HEINZE in your designs

NEW... BLOWER-HEATERS

for warming and drying

Heinze new Blower-Heater Combination Units are ideal for warming and drying in such applications as hot food vending machines, photographic dryers, food warmers. Blower is designed for continuous operation. Heater can be thermostatically controlled through separate terminals.

Motor operates on 110 V, 60 cycles. Type DS delivers 55 cfm (free air) at 3000 rpm. Type YSS delivers 50 cfm (free air) at 1500 rpm. Heaters are available from 200 to 1000 watts, single phase. Coiled wire heating element is well insulated to protect outer wall. Choice of mountings includes outlet or inlet, flat strap, or "L" shaped brackets.

Send coupon for complete technical data.

HEINZE ELECTRIC COMPANY
685 Lawrence St., Lowell, Mass.
Sub-Fractional Horsepower Motors and Blowers

HEINZE ELECTRIC COMPANY
685 Lawrence Street, Lowell, Mass.

Please send me literature and price information on Heinze Blower-Heater Combination Units.

Name & Title.....

Company.....

Street & No.....

City & State.....

Circle 479 on Page 19

Helpful Literature

naw Bearing Co., 821 Water St., Saginaw, Mich. H

Circle 597 on Page 19

Filters

Fulflo and CFC filtration equipment for micronic clarification of such fluids as lubricating and fuel oils, liquid chemicals, compressed air, carbon dioxide, hydraulic fluids, plating solutions, coolants and quenching oils, and insulating oils is covered in detail in illustrated catalog. Commercial Filters Corp., 2 Main St., Melrose, Mass. B

Circle 598 on Page 19

Permanent Magnets

"Design and Application of Permanent Magnets" is number 6 in the Permanent Magnet Manual series. Engineering factors to be considered, actual design problems, a glossary of magnetic terms, symbols used in design calculations, conversion factors, and a design guide are some of the engineering aids presented. 32 pages. Indiana Steel Products Co., Valparaiso, Ind. J

Circle 599 on Page 19

Time Delay Relay

Technical Bulletin TD 502 lists details and specifications of a subminiature hermetically-sealed time delay relay for military and aviation purposes. Delays range from 1 second to 3 hours, and ratings are up to 5 amp, 115/250 v ac. 2 pages. A. W. Haydon Co., Waterbury, Conn. B

Circle 600 on Page 19

Air Control Valves

Ball cam, palm button, hand lever, locking hand lever, and mechanical link clevis types of Flo-Pilot control valves for air operated equipment and mechanisms are subject of Catalog 252. Valves are available in ¼-in. pipe size for two or three-way operation on up to 150-psi pressure. "Idea Starter" control circuits are included. 8 pages. Hanna Engineering Works, 1765 Elston Ave., Chicago 22, Ill. I

Circle 601 on Page 19

Needle Valves

Features of two new globe type needle valves as well as design and application data are presented in illustrated brochure. 4 pages. Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. F

Circle 602 on Page 19

Air & Steam Cleaners

Description and cutaway drawing in Bulletin 502 shows how Model LC Hi-eF air and steam cleaners operate without use of moving parts, filters, or baffles. This construction prevents clogging, loss of pressure and eliminates maintenance. Selection tables are included. 4 pages. V. D. Anderson Co., 1935 W. 96th St., Cleveland 2, Ohio. F

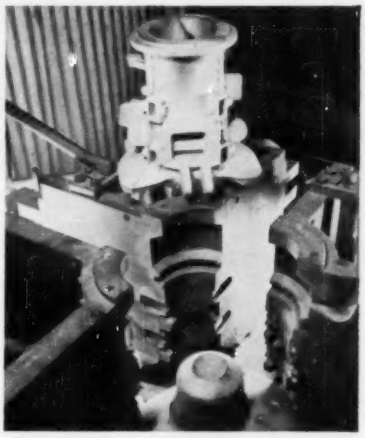
Circle 603 on Page 19

Thermoplastic Resin

Folio of application stories explains applications of Cycolac high-impact thermosetting resin in items produced by molding, extruding, and calendering processes. Characteristics of this

NEW DESIGN OPPORTUNITY

With Monarch Aluminum Permanent Mold Castings



Modern methods in mold designing—metallurgy—and mass production operations make Monarch Permanent Mold Castings more versatile to fully meet today's end-product requirements competitively.

From complicated industrial castings to finished consumer product castings, ready for assembly, Monarch's wide range of services offer "More Casting Value per Dollar".

This new approach to casting evaluation and "One Source" production in permanent mold—Aluminum Die Casting and Zinc Die Castings is presented in a new brochure, "Manufacturing Achievements in Molten Aluminum". Write for Your Copy Today.

MANUFACTURING in MOLTEN ACHIEVEMENTS ALUMINUM

MONARCH ALUMINUM MFG. COMPANY
9205 Detroit Avenue Cleveland 2, Ohio

Circle 480 on Page 19

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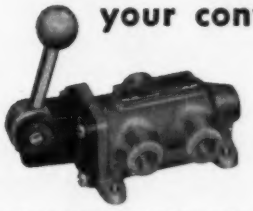
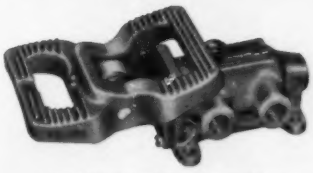
your one source for AIR VALVES

full line for every use—immediately available from your conveniently located Schrader Distributor

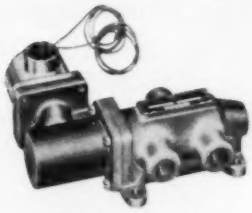


Hand-Operated Four-Way Valve



Foot-Operated Four-Way Valve

Pilot-Operated Valve



Solenoid-Operated Valve

Rotor Type Valve

Cam-Operated Valves

Flow Control Valves

Quick Exhaust Valves

Two- and Three-Way Poppet Type Valves with Roller Lever

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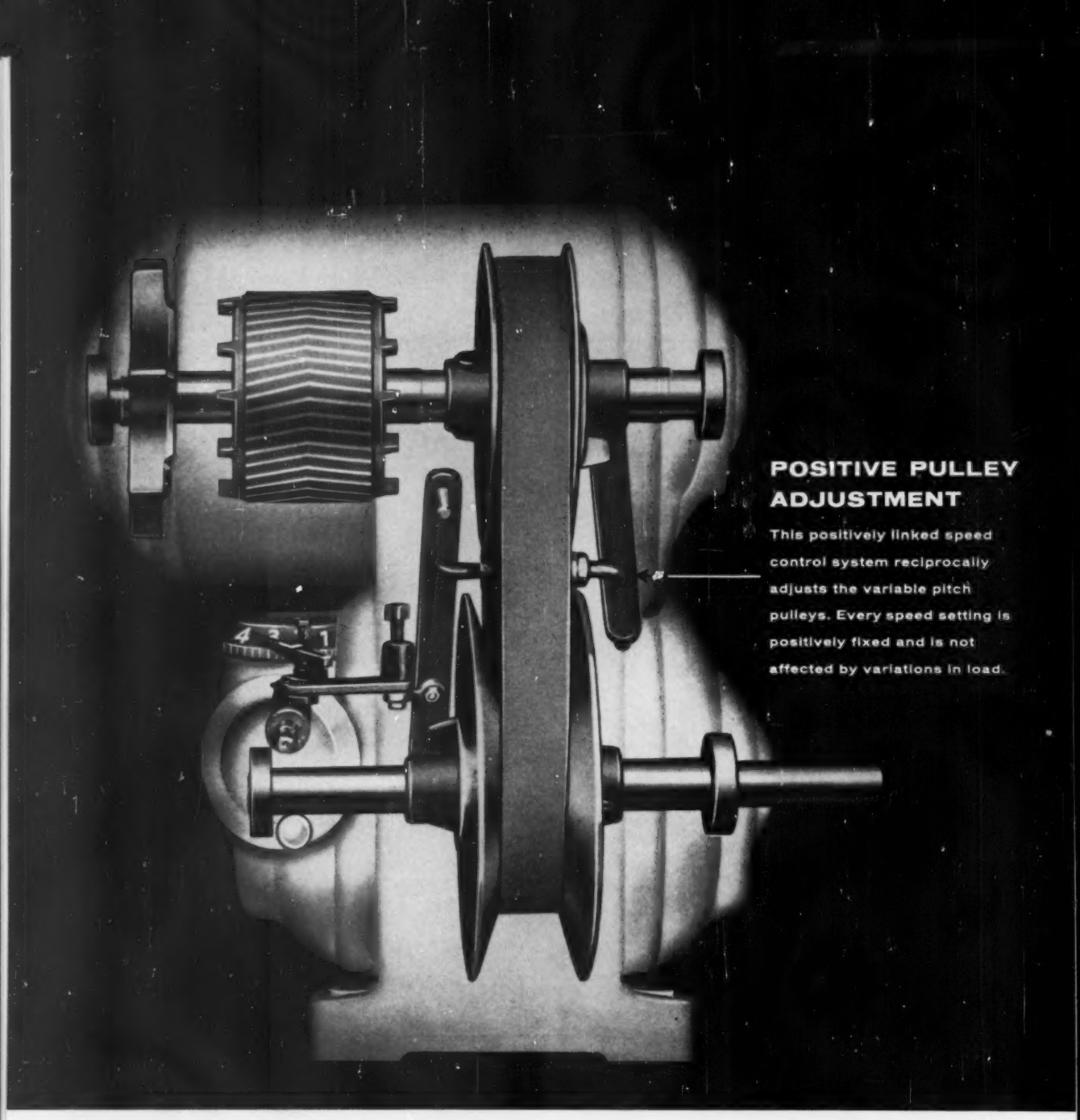
QUALITY AIR CONTROL PRODUCTS



POSITIVE PULLEY ADJUSTMENT

This positively linked speed control system reciprocally adjusts the variable pitch pulleys. Every speed setting is positively fixed and is not affected by variations in load.

New Worthington motor drive gives you

ACCURATE SPEED REGARDLESS OF LOAD

Once you set the speed on a Worthington variable speed motor drive, the pulley holds it – maintaining accurate speed control regardless of variations in load.

This unique feature is the result of "positive pulley adjustment." A positively-linked speed control system reciprocally adjusts the variable pitch pulleys. Unlike spring-equipped drives which constantly maintain maximum belt tension to meet occasional peak loads, belt tensions in a Worthington drive never exceed the actual load transmitted. Peak and momentary starting loads are transmitted just as smoothly as they would be with a standard fixed speed V-belt drive.

Positive pulley adjustment also results in a compact design with inherently long belt life. The wide-angle design of the belt offers deep side walls for greater contact area. This feature gives you high power capacity with minimum belt pressure. The large diameter belt assures smooth, efficient operation with little wear.

The new line is available in speed variations up to 10:1 and horsepower ratings from ½ to 25 hp. You can specify finger tip speed control or one of the many types of remote controls – both automatic and mechanical. For complete information, write for Bulletin 1610-B1. Address Section MV-78, Worthington Corporation, Oil City, Pa.

WORTHINGTON

Circle 482 on Page 19

Helpful Literature

plastic are explained. 19 pages. Borg-Warner Corp., Marbon Chemical Div., Gary, Ind. J

Circle 604 on Page 19

Thermostat Metals

Test results on various thermostat metals exposed to corrosive environments are summarized in Technical Bulletin TRU-6. Relative cost chart, comparative thermal deflection graph, and properties listing are included. 4 pages. Metals & Control Corp., General Plate Div., Attleboro, Mass. B

Circle 605 on Page 19

Limit Switch

Plug-in limit switch which can be replaced in seconds is described and illustrated in Bulletin 20. Five actuator types are covered, as are specifications, mounting data, and prices. Oiltight unit has long life. 4 pages. Minneapolis-Honeywell Regulator Co., Micro Switch Div., Freeport, Ill. K

Circle 606 on Page 19

Plant Facilities

"Solar Advanced Technology" is title of brochure which details company's engineering and research facilities, fabrication, gas turbine engines, missile capabilities, and aircraft engine and industrial products. 14 pages. Solar Aircraft Co., 2200 Pacific Highway, San Diego 12, Calif. L

Circle 607 on Page 19

Dust & Products Collectors

Full design details, including engineering drawings and dimension tables are featured in Bulletin 150-A on Cyclone, Hi-Spin dust and products collectors. Units are designed for uses where air is employed to handle feed, foods, chemicals, or hazardous materials. 4 pages. Sprout, Waldron & Co., Muncy, Pa. E

Circle 608 on Page 19

Protected Motors

Discussed in illustrated Bulletin B-2506 are totally-protected motors in ratings from 1 to 125 hp. Design features are explained. 4 pages. Reliance Electric & Engineering Co., 24701 Euclid Ave., Cleveland 17, Ohio. F

Circle 609 on Page 19

Shielding & Grounding Braid

Sample board of shielding and grounding braid offers actual samples of various standard sizes. Included are commercial type tinned copper braid in sizes from 1/8 to 11/16 in. and military braid which meets Federal specifications. Request on company letterhead from Lenz Electric Mfg. Co., 1751 N. Western Ave., Chicago 47, Ill. I

Rivets & Riveters

"Fastener Fact File" contains design and purchasing data on rivets and riveting machines. Many types of rivets are described and potential applications are shown. Specifications of available machines are given. 42 pages. Request on company letterhead from Judson L. Thomson Mfg. Co., Waltham 54, Mass. B

NOs for News

Our Laminum Shims are good news for thousands of metal working plants, because our "NOs" save time and reduce costs.

LAMINATED SHIMS OF

LAMINUM®

SURFACE BONDED . . . THEY peel FOR ADJUSTMENT

And only in Laminum are laminated, surface-bonded shims available in all four materials as shown below.

Laminated Shims of **LAMINUM** now available in

STAINLESS STEEL with laminations of .002" or .003"	**LOW CARBON STEEL** with laminations of .002" or .003"
BRASS with laminations of .002" or .003"	**ALUMINUM** with laminations of .003" only

LAMINATED SHIM COMPANY, INC.

Shim headquarters since 1913

1201 Union Street, Glenbrook, Conn.

Circle 483 on Page 19

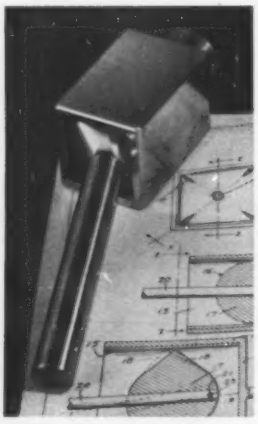
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Universal Joint

has one-piece head construction

This universal joint performs well over a wide angle range. It consists of a female member, a housing with square cross-section, and a male member with a metal or plastic head on an extended shaft. Head fits snugly in the square housing at various angles, and turns freely and functionally. Of one-piece head construction, joint has a large drive area. Ball-and-socket design can be incorporated to provide a fastened joint. Size



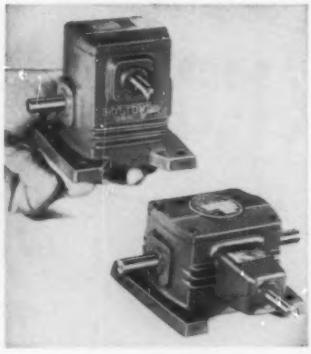
of the joint is varied to meet applications. Joint shown is 1½ in. across the square of the male portion; shaft is ¾ in. in diam, and outside of female member is 2 in. across. **Kvalheim Machinery Co.**, P. O. Box 77, Petaluma, Calif. M

Circle 610 on Page 19

Speed Reducers

for light-duty applications

Three small speed reducers are available for light-duty applications. Model R113 (bottom) is a miter-gear reducer with 1:1 ratio and horizontal right-angle drive. It weighs 3.75 lb, and has rated



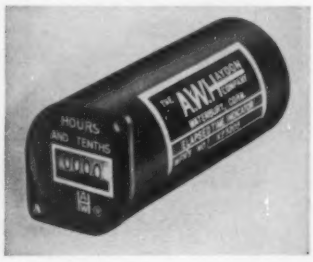
output ranges from 0.03 to 0.333 hp. Model T109, a worm gear assembly, is designed with the worm gear over. Model U109 (top) has the worm gear under. Ratios for both range from 5:1 to 30:1, and output from 0.03 to 0.08 hp. **Boston Gear Works**, Quincy 71, Mass. B

Circle 611 on Page 19

Elapsed-Time Indicators

subminiature units meet military requirements

Series 25200 subminiature hermetically sealed elapsed-time indicators are available with 400-cycle motors for operation on 115 v. Designed to meet military requirements, they are available with two dial styles and two mounting options. Shown is a digital version with compact flange mounting. A five-digit, nonreset type counter totalizes to 9999.9 hr. Another type uses a dial with two hands. Sweep hand reads to 100 hr in 5-hr increments, and totalizer hand



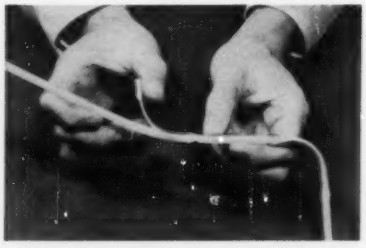
reads to 2500 hr in 100-hr increments. **A. W. Haydon Co.**, 232 N. Elm St., Waterbury, Conn. B

Circle 612 on Page 19

Tube-Bending Clip

holds 90-deg bend in ¼-in. OD tubing

Tube-bending clip is designed to hold a permanent 90-deg bend in ¼-in. OD plastic tubing. Bend radius is 1 in. Clip is manually attached by snap-on procedure, and can be removed easily and



placed at another location on the tubing. **Polymer Corp. of Pennsylvania**, 2140 Fairmont Ave., Reading, Pa. C

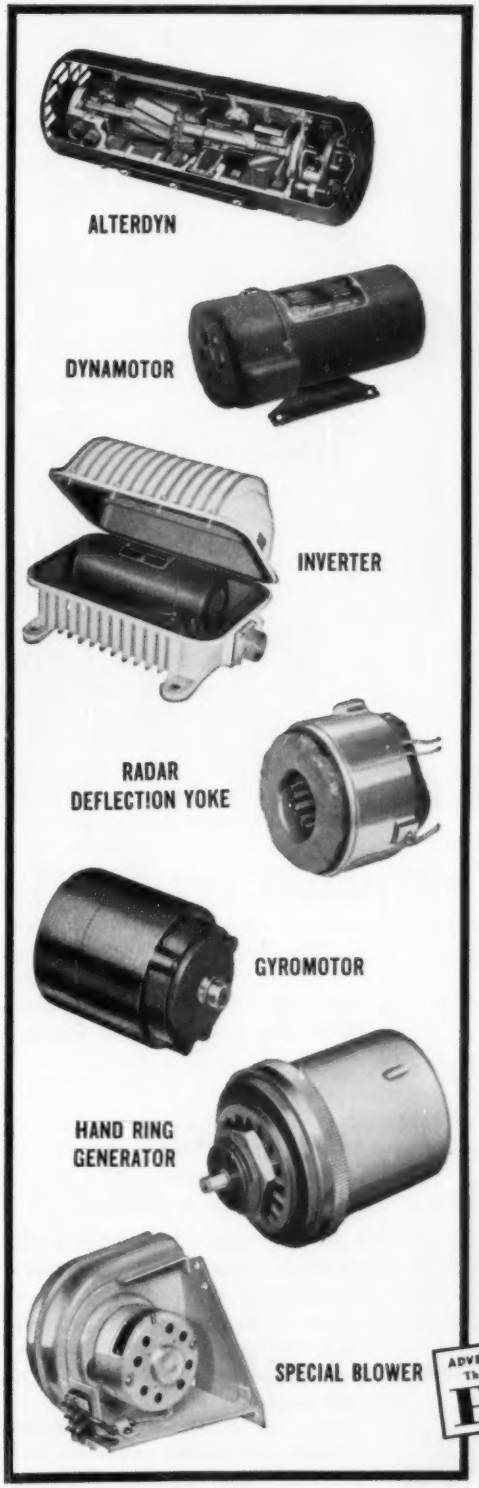
Circle 613 on Page 19

Unijunction Transistors

operate like controlled-grid thyratrons

Six silicon unijunction transistor-type units, designated 2N489 through 2N494, exhibit open-circuit-stable negative resistance characteristics. Operating like controlled-grid thyratrons, they are particularly useful in switching and oscillator circuits. Units sense voltage levels and temperature variations, or, by various circuit modifications, can be made insensitive to the variations. Applications include relaxation oscillators, sawtooth and pulse generators, pulse-rate modulators, pluse amplifiers, multivibrators, flip-flops, and time-delay circuits. Transistors are

Call on *Redmond* to Design, Develop, and Produce Rotating Electrical Mechanisms



Whether your needs are for military or civilian specifications, Redmond has the development, testing, inspection, and packaging facilities to meet them.

Through the years Redmond has developed many mechanisms in the fractional horsepower field. Some of the products that either are being or have been produced in volume by Redmond are illustrated at the left. In the alterdyn, Redmond combined the dynamotor and inverter in one package. In dynamotor development, Redmond has reduced weight and frame size to a minimum. Other products are 400 cycle motors and actuator motors.

As the leading manufacturer of fractional horsepower electric motors, the Redmond Company is in a position to design, develop, and produce rotating electrical equipment. At the same time, the standard line of Redmond products can frequently be modified to meet performance and specification requirements.

Telephone, write, or wire Redmond Co., Inc., Special Products Division, Owosso, Michigan, and your problems will be given our immediate attention.

The Standard of Dependability

Redmond

COMPANY, INC.

OWOSSO, MICHIGAN

ADVERTISED IN The Saturday Evening POST

THE **BIG** NAME IN SMALL MOTORS

SEALING DOMESTIC APPLIANCES IS A REAL CHALLENGE, TOO!
Standard 6A Seal with specially designed seat conforming to impeller contour so as to promote good water flow characteristics.
Limited axial room and large diameter are mechanical requirements in this washing machine seal. Design features multiple spring construction for even face loading.
FIVE ADAPTATIONS OF THE John Crane
TYPE 6A SEAL
for four different appliance manufacturers
Seal features outer periphery face construction to best service garbage disposal conditions.
Two sealing points in a washing machine with widely differing physical limitations, yet seals for both retain full advantage of diaphragm action, shouldering points and positive drive.

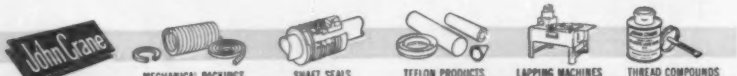
Soapy water, detergents, bones, grit and lint . . . all these combine to make appliances a hard-to-handle sealing problem. Add that to a very limited space factor, and you've got a real set of conditions on your hands.

"John Crane" engineers have solved these problems and thousands of other shaft sealing applications on all types of commercial and industrial equipment. We know that we can be of the same help to you.

That's why . . . as one design engineer to another . . . we urge you to let us work with you in adapting or developing the proper seal for your application.

Tell us about your requirements or write for our fully illustrated Bulletin S-204-3 on "John Crane" Shaft Seals.

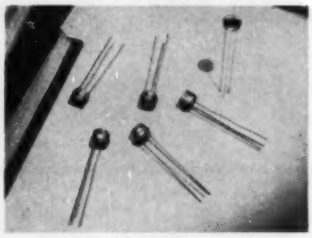
Crane Packing Company, 6425 Oakton Street, Morton Grove, Illinois, (Chicago Suburb). *In Canada: Crane Packing Co., Ltd., Hamilton, Ont.*



CRANE PACKING COMPANY

Circle 485 on Page 19

New Parts



useful in medium-power switching and oscillator applications where one unijunction transistor serves the purpose of two conventional units. Maximum power-dissipation rating for all units is 250 mw at 25 C. Operating temperature range is from −65 to 150 C. **General Electric Co.,** Semiconductor Products, Electronics Park, Syracuse, N. Y. C

Circle 614 on Page 19

Reinforced Plastic Material

for high-temperature use

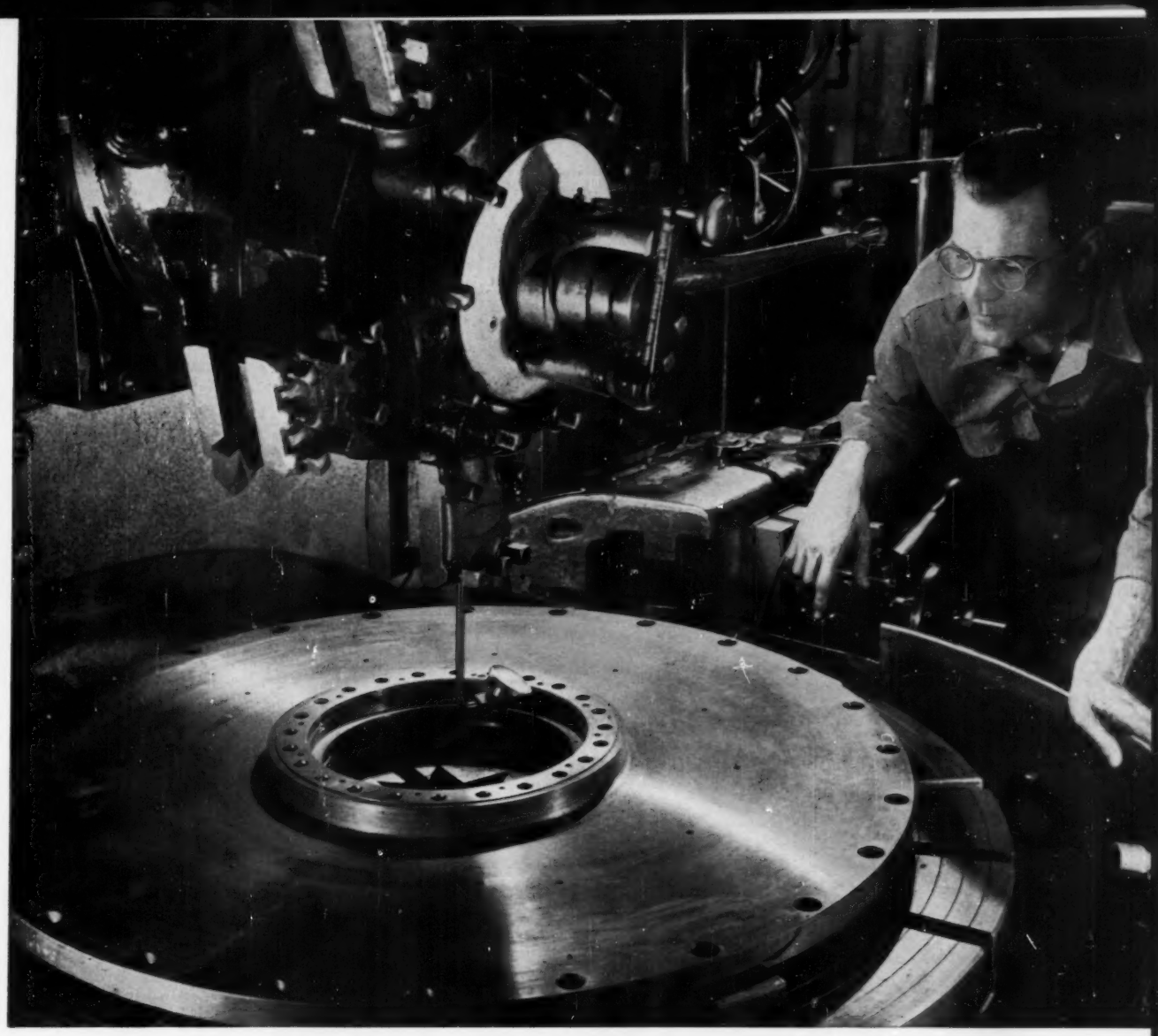
Astrolite is a reinforced plastic material containing laminations of near-pure silica fibers. Material resists extremely high temperatures (5000-F range) for relatively long periods, and can be used for short-interval performance at higher temperatures. Material is for use as insulation in rockets and missiles. It has excellent thermal-shock characteristics. Two types of preimpregnated Astrolite cloth are presently available. Both are furnished in either vacuum bagging or press-molding grades, and are also supplied as chopped fabrics on request. Fabricated parts of the material are also available. **H. I. Thompson Fiber Glass Co.,** 1733 Cordova St., Los Angeles 7, Calif. L

Circle 615 on Page 19

Leakproof Gaskets

seal at pressures from vacuum to 5000 psi

Leakproof static seals with full metal-to-metal contact are suitable for sealing in a wide range of fluids at pressures from vacuum to better than 5000 psi, and at temperatures from −80 to 500 F. The one-piece gaskets, in addition to usage as static seals between flanges, can be used as orifices, cover plates, and spacers. Units are



The Most Important Difference is Down Inside

Differences *do* exist in circular steel blanks. We don't mean variations in size, thickness, etc.; we mean the differences in quality that are rarely apparent from mere surface inspection.

For years Bethlehem has made circular blanks by a method that both *forges* and *rolls* the steel in a single operation. Is this of any interest to the user? Does it bring about differences that are really important?

The answer is a big, emphatic yes! Bethlehem's unique method of manufacture insures such advantages as soundness, excellent grain flow, and very high strength. Because of these characteristics, the machinist can always do his job with complete confidence; there are no hidden flaws to snag the cutting tool, slow the work, or cause rejections.

If you build machinery that requires circular steel parts, especially parts for heavy-duty service, we strongly recommend Bethlehem blanks. They are suitable for such a long list of applications—flywheels, sheave and crane wheels, gears, turbine rotors, clutch drums, brake wheels, and many others. The blanks range in size from 10 to 46 in. OD, and they can be furnished heat-treated or untreated. Prices are fully competitive.

Write for a free copy of Booklet 216. Its numerous pictures and clearly written text will answer many questions that may occur to you.

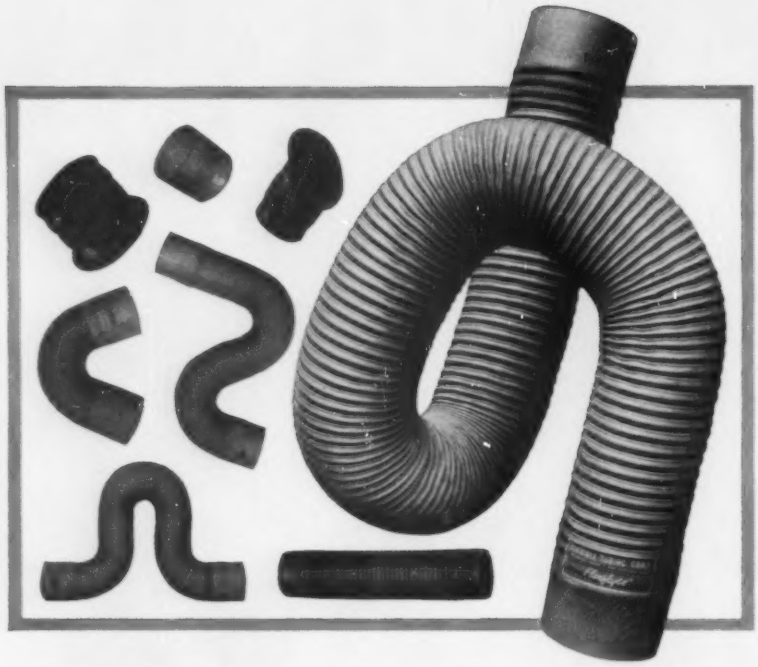
BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle 486 on Page 19

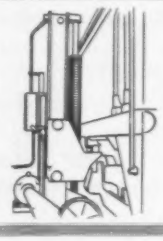


Here's why so many of today's specs call for FLEXIBLE TUBING products

Flexible Tubing has a thorough understanding of industry's ducting needs. Close collaboration with design engineers and trouble-shooting trips—hundreds and hundreds of them—have familiarized our engineers with countless ducting problems. Each successive job we've tackled has added to our knowledge of ducting behavior. And over the years we've acquired the facilities and equipment needed to meet any requirement. We now have completely integrated plants for development and production on both coasts.

Our present line of flexible ducting is the most complete, most diversified in the industry and we're always prepared to vary or modify any part of it. In the panel below we mention several recent applications for Flexflyte and Spiratube—lightweight ductings available with special fabrics and coatings for a wide range of temperature and pressure applications.

The background and experience of our field engineers are at your service. Let us know your requirements and we'll be glad to have one of them stop by to talk over your problems. For full information, write Dept. 181.



Example

Spiratube used as protective covering on actuating screw of railroad car boot jack.

Other typical applications

Flexflyte: feeder tubes for gluing machines; organ piping connections; sander tubes for railroad cars; connector ducts from abrasive wheels to dust collectors on buffing and tire-truing machines.
Spiratube: crop drier hose; for dust collecting from multiple drill rig; for venting cooling air from diesel locomotives.

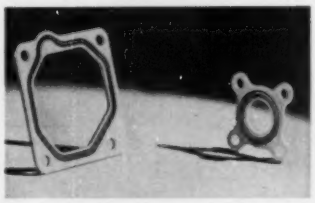
Flexible Tubing

CORPORATION

GUILFORD, CONNECTICUT

ANAHEIM, CALIFORNIA • HILLSIDE, ILLINOIS

New Parts



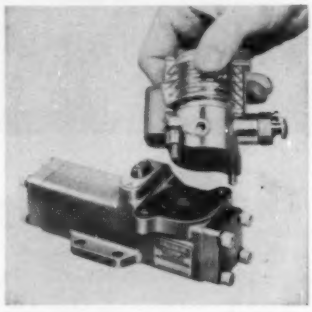
lightweight and reusable. Still-Seal Gasket Dept., **Stillman Rubber Co.**, 5811 Marilyn Ave., P. O. Box 1097, Culver City, Calif.

Circle 616 on Page 19

Control Valves

have built-in plug connectors

Speed King plug-in ¼-in. four-way control valves incorporate built-in plug connectors for fast, automatic connection of electrical circuits. Plugs and connectors, incorporated in solenoid pilot, valve body, and manifold or sub-base, complete all electrical circuits automatically when unit is placed in mounting position. Valves are designed for control of small devices, and are available in both single and double-solenoid types. De-



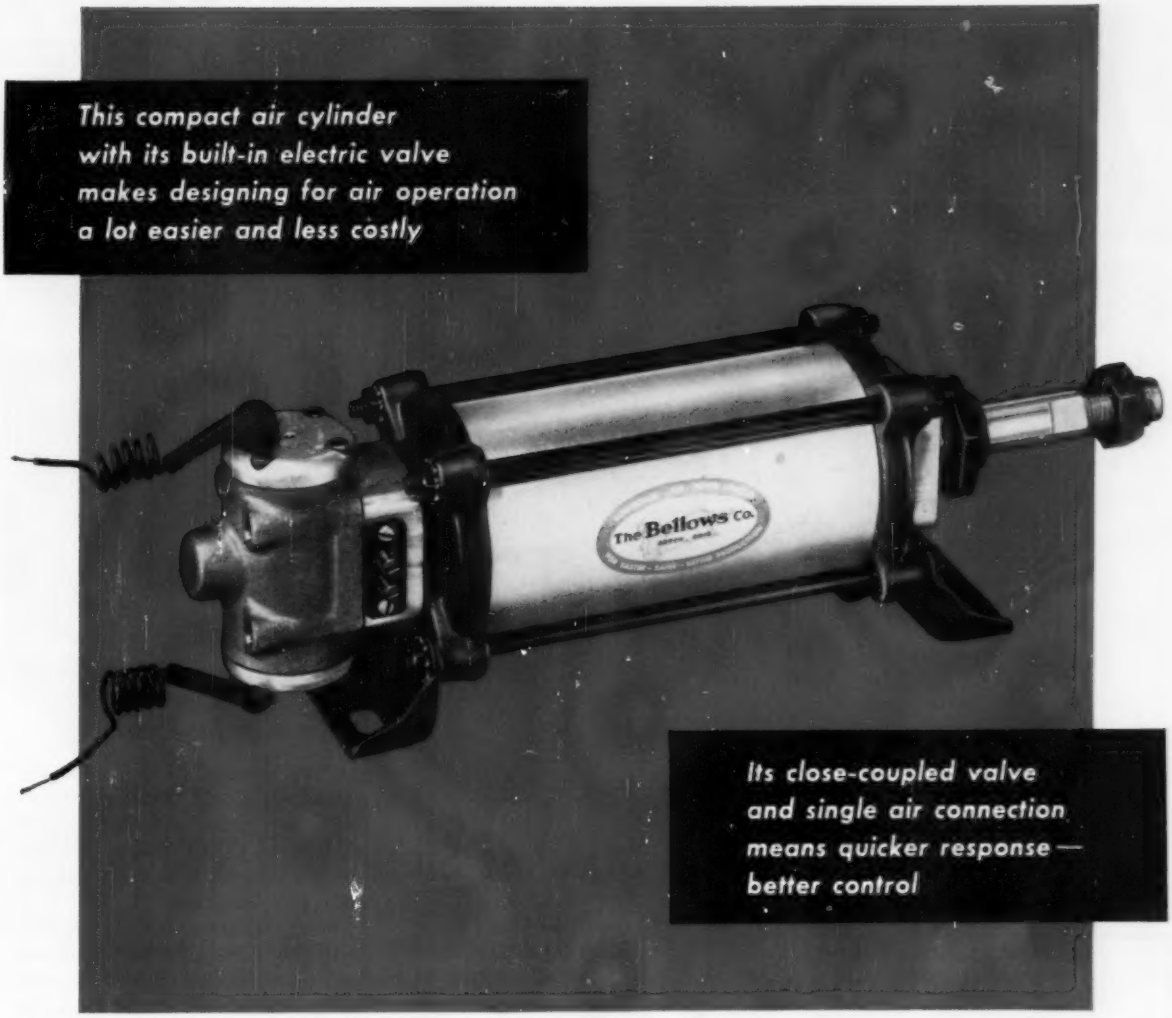
signed for 30-250 psi air service, valves are offered with solenoid coils for ac or dc, any voltage. **Valvair Corp.**, 454 Morgan Ave., Akron, Ohio. F

Circle 617 on Page 19

Self-Tapping Insert

accommodates standard threaded fasteners

H-Series Tap-Lok insert incorporates three holes in the pilot to provide balanced thread-cutting action. Truncated external thread roots give 20 per cent more wall thickness, with increase in insert strength. Internal threads run the


This compact air cylinder with its built-in electric valve makes designing for air operation a lot easier and less costly
The Bellows Co.
Its close-coupled valve and single air connection means quicker response—better control

ONE QUICK LOOK TELLS YOU WHY THE BELLOWS AIR MOTOR MEETS ORIGINAL EQUIPMENT DESIGN NEEDS SO PERFECTLY

As you can see, it takes but little more space, built-in valving and all, than a conventional air cylinder alone, without valve. Its single air connection (which can be inexpensive and easily installed flexible hose) makes it simple to install on moving machine elements. Its low voltage (8-12 v.) electrically controlled valve* permits less costly wiring, simpler hook-up, and easy interlock with related movements.

1013-B

The Place of the Bellows Air Motor in Original Equipment Design is the subject of a 16-page bulletin. We'll be happy to send you a copy without cost or obligation. Write Dept. MD-158, The Bellows Co., Akron 9, Ohio. In Canada: The Bellows Pneumatic Devices of Canada, Ltd., Toronto 18.

What you can't see in the picture is equally important. With the Bellows Air Motor comes the skill and service facilities of more than 125 full time Bellows Field Engineers—men as near you as your phone. They will work with you in applying Bellows "Controlled-air-power" to your designs and they're available quickly to meet any service need.

In your OEM planning take advantage of the savings "Controlled-air-power" offers—and as most manufacturers do—talk to Bellows.

*115 v. for J.I.C. applications, if you prefer.

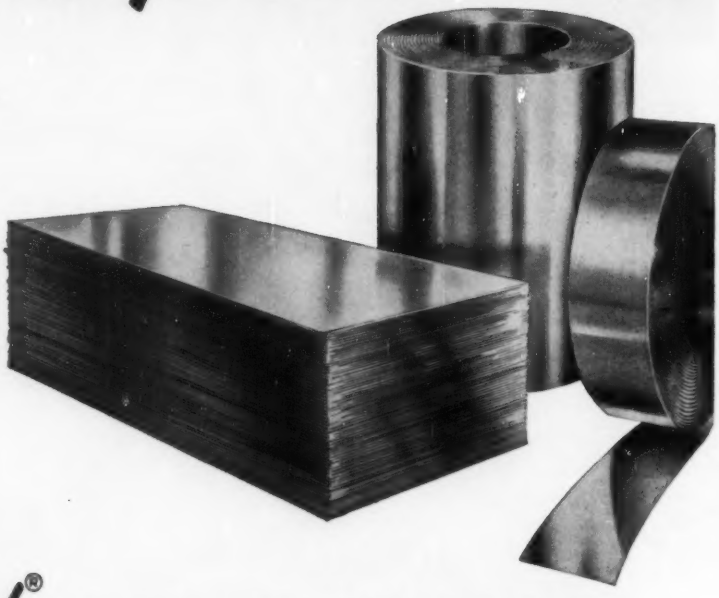
The Bellows Co.

DIVISION INTERNATIONAL BASIC ECONOMY CORPORATION

AKRON 9, OHIO

Circle 488 on Page 19

Wherever you are you get *quick personal service*



when you order *MicroRold*® Stainless Steel Sheet & Strip

SPECIFICATIONS	WIDTH	THICKNESS
SHEETS	up to 36″	.005 to .109
	up to 48″	.010 to .109
STRIP	up to 23 15/16″	.0015 to .090
GRADES:	201, 202, 301, 302, 304, 305, 316, 321, 347, 403, 410, 430 and Micro-Mach (special extra-high-tensile aircraft grade)	

Any one of the 305 independent steel warehouse distributors stocking MicroRold Stainless Steel is ready to serve as your *personal* stainless procurement representative. Located strategically in the U. S. A., Canada and Europe, your MicroRold distributor carries a variety of grades, widths, thicknesses and finishes and is fully qualified to assist you in the selection and fabrication of the most suitable stainless grade for your particular requirements.

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You can rely on MicroRold service as a dependable source of supply, either mill or distributor delivery.

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WASHINGTON STEEL CORPORATION

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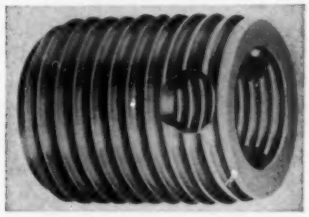
full length of the insert, to Class 2B or 3B specifications. Insert is available in three standard lengths in cadmium-plated steel or stainless steel, for self-tapping into alu-



minum, magnesium, and other structural materials. It accommodates standard threaded fasteners without stripping, and withstands vibration without loosening. **Groov-Pin Corp.**, 1125 Hendricks Causeway, Ridgefield, N. J.

Circle 618 on Page 19

Heat-Resistant Alloy

for temperatures to 2150 F

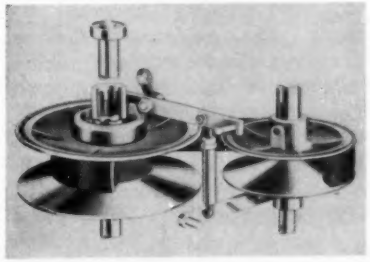
Iron-chromium-aluminum alloy, designated Alloy 815, is for use on small appliances and industrial heating devices where continuous operating temperatures do not exceed 2150 F. Material has high resistivity, low specific gravity, and high resistance to oxidation. Alloy is also suitable for heavy relay switches and other equipment where cold forming is required. **Hoskins Mfg. Co.**, 4445 Lawton Ave., Detroit 8, Mich. H

Circle 619 on Page 19

Adjustable-Speed Drives

have positive pulley control

New line of mechanical adjustable-speed drives, designated Type W, provides infinitely adjustable speeds from 4600 to 1.2 rpm in speed variations of 2:1 to 10:1. Units accomplish speed variation by means of a ribbed V-belt



The valve that outlasts the equipment!

- ✻ New, unique plunger seal design
- Soft rubber seal assures bubble-tight sealing.
- Completely dependable for millions of cycles.
- Full operation in any position.
- Stainless steel internal construction, brass body.
- Easy to disassemble and clean.
- Smaller... Lighter.

Last longer than other valves... yet only $6.50 list.

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VALCOR SV-4900 series...2.35" high by 1.50" wide...available 7/64 orifice rating 130 PSI max. and 5/32 rated 60 PSI max. ...for use with water, air, steam, inert gases, petroleum and vegetable oils, gasoline, kerosene and many other semi-corrosive media...and they are stocked for off-the-shelf delivery.

WRITE for VALCOR Catalog 105, plus information on the many VALCOR valves available.

VALCOR ENGINEERING CORP.
5365 CARNEGIE AVE.
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VALCOR SOLENOID VALVES

Circle 490 on Page 19

"Nous Sommes Ici!"

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WHEELOCK, LOVEJOY & COMPANY, INC.

133 Sidney Street, Cambridge 39, Mass.

Circle 492 on Page 19

New Parts

and dual variable-pitch pulleys mounted on parallel shafts. Movement of pulleys is synchronized by positive pulley control which can be adapted to manual, semiautomatic, or automatic controls. Two basic models include integral motor and separate motor construction. **Sterling Electric Motors Inc.**, 5401 Telegraph Rd., Los Angeles 22, Calif. L

Circle 620 on Page 19

Control Valve

has pressure rating of 10,000 psi

Type 505 control valve handles gases and liquids in high pressure drop, on-off, or throttling service, with dead-end shutoff. The split-body valve has a pressure and temperature rating of 10,000 psi at −40 to 400 F. It is available with direct or reverse-action actuator, with standard 3-15 and 6-30 psi instrument air range. Body is forged stainless steel with hardened stainless-steel trim. Connection sizes are ½ and ¾ in. NPT. Connections for high pressure tubing are also included. **A. W. Cash Co.**, P. O. Box 551, Decatur, Ill.

Circle 621 on Page 19

Circuit Breakers

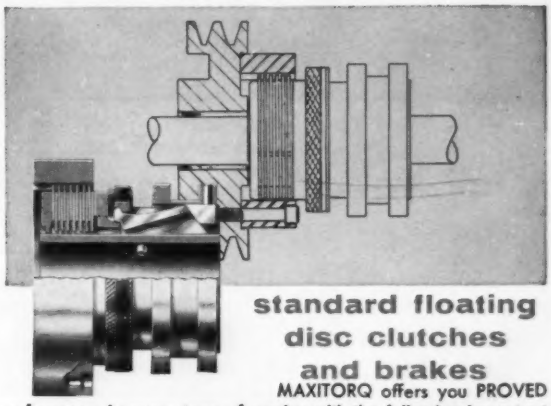
for 120 and 480-v service

Two redesigned molded-case AB circuit breakers are more compact and have increased electrical capacity. They are suitable for use in custom panelboards and electrically driven industrial equipment. The two units are a three-pole, 480-v breaker and a single-pole, 120-v breaker (shown). The 480-v unit has ratings from 15 to 100 amp ac and withstands short-circuit currents of 10,000 amp. The

if your design calls for CLUTCHES

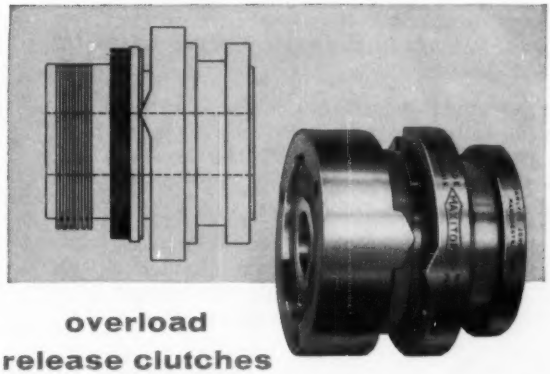
MAXITORQ electric clutches and brakes

PROVED design, Floating Disc action is fast and positive, with no heating or drag in neutral. Compact, simple, with few moving parts. For WET or DRY operation: Electrical operating unit DOES NOT REVOLVE; no brushes or slip rings. Use easily replaced standard Disc-Pac. Requires no adjustment. Wide range of standard sizes, single and double types. All sizes rated 80 watts, operate on 110 V, A.C., rectified to 90 V, D.C. Other voltages on special order.



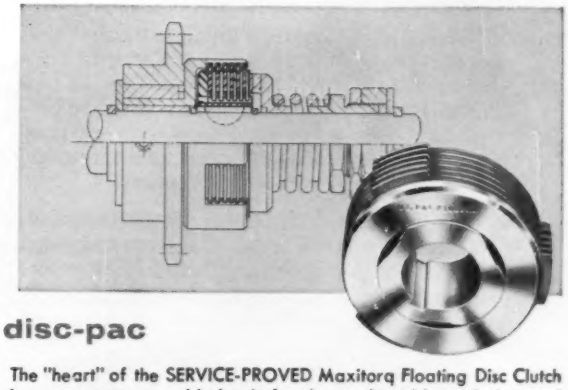
standard floating disc clutches and brakes

MAXITORQ offers you PROVED performance in every type of service with the following important advantages: compact design with few and sturdy parts . . . floating neutral with no heating or drag . . . positive engagement or release with light pressure . . . manual assembly and adjustment . . . full power transmission . . . full range of sizes and types . . . supplied as complete, easily installed units.



overload release clutches

One of the simplest and most efficient methods of providing a DEPENDABLE and easily adjusted overload release on machines requiring this safety feature in addition to a clutch. Incorporate all the advantages of MAXITORQ Floating Disc design plus automatic and complete release upon overload. Proved in service. Available in a wide range of sizes.



disc-pac

The "heart" of the SERVICE-PROVED Maxitorq Floating Disc Clutch in a compact, assembled unit for those who wish to design and build their own clutch mechanisms. Supplied as complete units ready for use in 8 diameters 2" to 8", up to 800 ft. lbs. capacity. Also useful as a multiple disc brake or torque limiting device.

Write for complete data and specifications on any or all of the above. If you have a problem involving clutch applications, consult us. A letter or phone call will receive prompt attention. Dept. MD-1.

THE CARLYLE JOHNSON MACHINE COMPANY, MANCHESTER, CONN.

Want to SAVE up to 70% of heating costs on your phosphate coating line?

new Parker Cold Bonderite System does it!

Turn down the heat! Put most of your Bonderite line heat costs back in the till! Parker Rust Proof Company has developed a new Bonderite system for low temperature operation.

It includes a new cold alkaline cleaner that works beautifully at 70° and is effective in a temperature range from 60° to 120°. A new Spra-Bonderite, specially formulated to produce a superior coating at low temperatures, has been developed to work in conjunction with the new Parker cold cleaner.

With the new cold Bonderite system, savings are really sizable. Heat consumption in the line is cut by as much as 70%. Cost of the new Parker system is approximately equal to conventional alkali cleaners and phosphate coating chemicals, so the savings in heat are practically all velvet. It is estimated that on an average automobile body line the savings in steam costs can run as high as 10 to 12 cents per body; on an average refrigerator line 4 to 5 cents per cabinet. Savings in B.T.U.s can mean savings in dollars.

The new cold Bonderite system has been production-tested in mass production plants. Its performance has amazed the experts. It's ready to go to work in your plant, saving you money, right now!

Why go on paying for heat you don't need? Start using Parker's new cold Bonderite system. A letter or phone call will bring a Parker man with full, money-saving details.

*Bonderite, Bonderlube, Parco, Parco Lubrite—Reg. U.S. Pat. Off.

PARKER RUST PROOF COMPANY
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BONDERITE and BONDERLUBE aids in cold forming of metals

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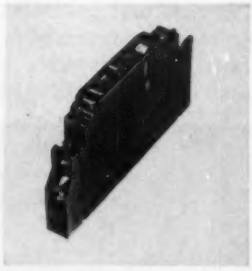
TROPICAL heavy duty maintenance paints since 1883



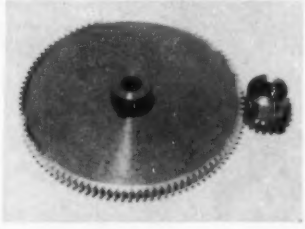
120-v unit has ratings of 15 and 20 amp, in a case only 11/16 in. thick. Both units have true ambient compensation, thermal-magnetic tripping for short-circuit protection, welded silver-tungsten contacts, center handle trip position, and legible position and rating markings. Pressure-type solderless connectors approved for No. 14 and No. 6 conductors are supplied. **Federal Pacific Electric Co.**, 50 Paris St., Newark 1, N. J.

Circle 622 on Page 19

Spur Gears

in bore sizes of 1/8 to 1/4 in. diam

Type G 24 and 32-pitch precision spur gears are cut to AGMA Precision 1c tolerances. They are of stainless steel, aluminum, nylon, and phenolic materials, and are



available in bore sizes from 1/8 to 1/4 in. diam. **PIC Design Corp.**, 477 Atlantic Ave., East Rockaway, N. Y.

Circle 623 on Page 19

Wire-Handling Guides

speed wire-handling operations

AlSiMag wire-handling guides speed almost any type of wire handling, such as winding, dipping, coiling, and forming. Guides, available in a series of hard Alumina compositions, are homogeneous and wear-resistant. Precision toler-

No. 25 Actual Size Pitch 1/4" Width 1/8"
No. 35 Actual Size Pitch 3/8" Width 3/16"
No. 41 Actual Size Pitch 1/2" Width 1/4"
No. 40 Actual Size Pitch 1/2" Width 5/16"
USE ACME CHAIN FOR EVERY POWER TRANSMISSION REQUIREMENT:
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Acme Chains are efficient, economical and positive for power transmission. They are readily adaptable to any drive when maximum efficiency is essential. Correct principles of design provide operating characteristics superior to any other method of power transmission. Replacement parts always readily available from stock.
Your inquiry will place a skilled Acme engineer at work on your power transmission problems.
No. 50 Actual Size Pitch 5/8" Width 3/8"
CONVEYOR CHAIN STANDARD and OVERSIZE ROLLERS
Acme Chain is obtainable in sizes from 1/4" Pitch — 1/8" Width to 2 1/2" Pitch — 1 1/2" Width.
CABLE CHAIN
Complete line of stock bore, steel and cast iron single sprockets, cast iron hub sprockets and all steel split or solid hub sprockets available.
ROLLER CHAIN SINGLE and MULTIPLE STRAND
FREE CATALOG
Write Dept. 6-O for your 80 page copy of Acme's latest catalog. Packed with valuable data.
Call ACME for Service
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HOLYOKE MASSACHUSETTS

Circle 495 on Page 19

Multi-Purpose Single Face "V" Ring.

Floating Labyrinth Seal for temperatures as high as 1400°F. and shaft speeds up to 150,000 rpm.

Metal Bellows Seals to fit any shaft size. Also: Cartridge Seals and Grommet Seals.

CUSTOM-ENGINEERED
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Cartriseal solves seal problems of high rpm, temperature extremes, corrosion. Send specifications. No obligation.

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Circle 496 on Page 19

"Round and round," said Galileo

First with the telescope to discover Saturn's Rings, Galileo would no doubt marvel today at the all around perfection of Universal *Precision* Balls. Metallic or non-metallic materials—both are lapped to classic tolerances as fine as 0.000005 of an inch.

It's real round if it's a Universal Precision Ball.

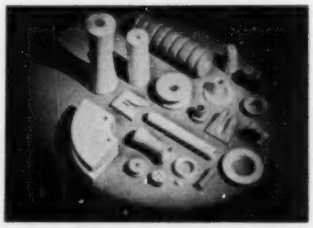
UNIVERSAL QUALITY CONTROL—FOR ALL AROUND PERFECTION

Universal Ball co.
WILLOW GROVE, MONTGOMERY CO., PA.

Circle 497 on Page 19

New Parts

ances permit highly mechanized wire processing. Standard designs are available; custom guides can be produced in almost any size and



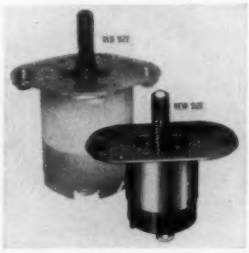
shape. **American Lava Corp.**, Cherokee Blvd. & Manufacturers Rd., Chattanooga 5, Tenn.

Circle 624 on Page 19

Miniature Toggle Switch

is high-capacity, heavy-duty unit

Designated No. 446152, new toggle switch is a positive-action, single-pole, four-position unit internally sealed with a silicone boot that keeps moisture and dust away from silver alloy contacts. A high-capacity, heavy-duty miniature unit, it is 1.8 cu in. in size and weighs 2 oz. Unit breaks inductive loads at high altitudes, and



operates actuators direct, eliminating relays. It meets applicable military specifications. **Mason Electric Corp.**, 3839 Verdugo Rd., Los Angeles, Calif.

Circle 625 on Page 19

Flexible Coupling

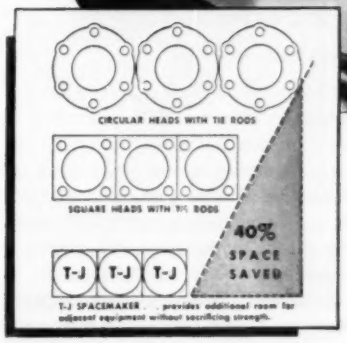
is available in 1/12 to 30 hp

Positive power transmission of the rated load in the Gear Grip flexible coupling is achieved by matching gear teeth of the end fittings with gear section of rubber tube. Coupling is available in 1/12 to 30-hp ratings. Coupling is manufactured in six basic hub sizes with

all the EXTRAS are standard with T-J Spacemaker CYLINDERS

Member of the National Fluid Power Association

- **NEW** *exclusive* ingenious cushion designs . . . Super Cushion Flexible Seals for Air . . . New Self-Aligning Master Cushion for Oil.
- **STRONGER** than outmoded tie rod design, proven through actual tests. No tie rods to stretch.
- **SOLID STEEL HEADS** throughout the full line.
- **COMPACT DESIGN** eliminates tie rods, increasing the strength and reducing mounting space required, providing extra room for adjacent equipment.
- **HARD CHROME PLATED** body bores and piston rods . . . assure you of long trouble-free service. (Standard at no extra cost.)
- **METALLIC ROD SCRAPER,** not just a wiper, actually removes foreign matter from the rod.
- **PILOTED PACKING GLAND** with extra long bearing. Additional strength and support to the piston rod.
- **OIL** pressure to 750 p.s.i. AIR to 200 p.s.i.


CIRCULAR HEADS WITH TIE RODS
SQUARE HEADS WITH TIE RODS
40% SPACE SAVED
T-J
T-J
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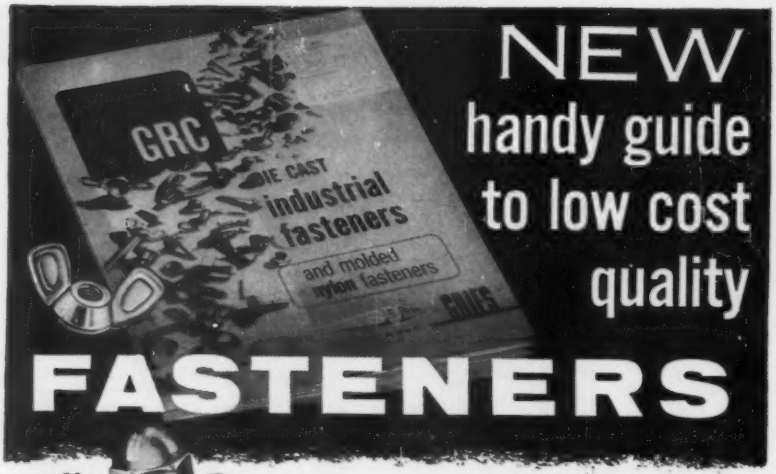
T-J SPACEMAKER . . . provides additional room for adjacent equipment without sacrificing strength.

DELIVERY OFF THE SHELF!

You *save 40% space* when you switch from outmoded tie rod cylinders to the T-J Spacemaker! It's stronger, too! Fits right into automation programs in countless plants. Delivers top performance and dependability with a big *plus* in advanced features. Wide range of styles, capacities . . . reduces man-hours and costs in all kinds of push-pull-lift operations. Off-shelf delivery in 64,000 combinations!

NEW LITERATURE—Send today for new Catalog SM56 with complete engineering details on Spacemaker line. Write The Tomkins-Johnson Co., Jackson, Mich.

T-J TOMKINS-JOHNSON
RIVITORS · AIR AND HYDRAULIC CYLINDERS · CUTTERS · CLINCHORS



NEW handy guide to low cost quality FASTENERS

Die Cast Zinc Alloy Wing Nuts • Cap Nuts
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GRC catalogs the widest range of stock styles, types, sizes and threads from one source . . . charts the dimensions of each style, type and size . . . illustrates them all with photographs and schematic drawings.

Detailed are uses, physical properties of zinc alloy and nylon, the many advantages of GRC fasteners . . . produced in one high speed automatic operation to assure quality fasteners at lowest cost.

Write, wire, phone RIGHT NOW for your copy of GRC's new Fastener Bulletin.

GRIES

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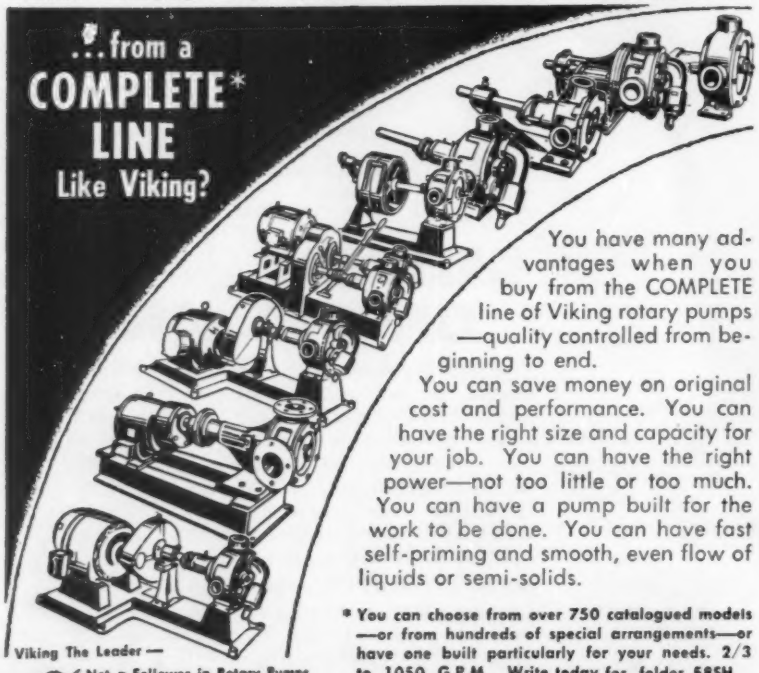
Circle 499 on Page 19

ARE YOU BUYING ROTARY PUMPS...

...from a COMPLETE* LINE Like Viking?



You have many advantages when you buy from the COMPLETE line of Viking rotary pumps —quality controlled from beginning to end.

You can save money on original cost and performance. You can have the right size and capacity for your job. You can have the right power—not too little or too much. You can have a pump built for the work to be done. You can have fast self-priming and smooth, even flow of liquids or semi-solids.

* You can choose from over 750 catalogued models —or from hundreds of special arrangements—or have one built particularly for your needs. 2/3 to 1050 G.P.M. Write today for folder 58SH

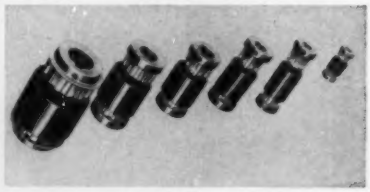
Viking The Leader— Not a Follower in Rotary Pumps

VIKING PUMP COMPANY

Cedar Falls, Iowa, U.S.A. In Canada, it's "ROTO-KING" pumps
See Our Catalog in Sweet's Product Design File

Circle 500 on Page 19

New Parts



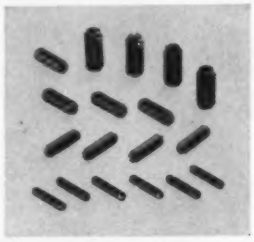
rubber variations to increase torque capacity for each hub size. Rubber section floats laterally between two captive end fittings, distributing the driving load similar to a universal joint. Coupling Div., Dept. A-6, **Guardian Products Corp.**, 1215 E. Second St., Michigan City, Ind.

Circle 626 on Page 19

Nylon Setscrews

are nonmagnetic and corrosion-resistant

Headless, slotted molded black nylon setscrews are nonmagnetic and have excellent insulating properties. Lightweight and tough, they resist corrosion. Screws are suitable for use in electronics, chemical, and other industries where critical service conditions exist. They are available in ½-in. length in 4-40, 6-32, 8-32, 10-32, and ¼-20



thread sizes. Shorter lengths are also available. **Weckesser Co.**, Dept. MDC, 5701 Northwest Highway, Chicago 30, Ill.

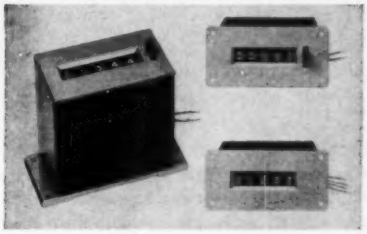
Circle 627 on Page 19

Electric Counter

has instant reset

YE high-speed electric counter operates at rates to 1500 counts per min. It can be reset instantly to zero, either electrically or with a pushbutton. Counter is designed for application in general industry and for incorporation on original equipment. It is available in four models with either panel or base mounting, and with electric or

pushbutton instant reset. Unit is adaptable to high-speed counting installations such as electronic computers, card and check sorters, electronic scalers, mailing equipment, military instruments, photoelectric and remote counting, test equipment, and light production



machinery. Unit counts accurately at high, low, or intermediate speeds. **Durant Mfg. Co.**, 1933 N. Buffum St., Milwaukee 1, Wis.

Circle 628 on Page 19

O-Ring Compound

is odorless and tasteless

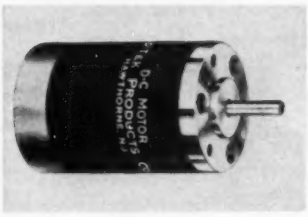
Compound 35-083 is an odorless and tasteless O-ring compound of 50 durometer hardness. It utilizes neoprene as a base material to meet broad usage requirements, including sealing applications in vending machines. Rubber Products Div., **Parker-Hannifin Corp.**, 17325 Euclid Ave., Cleveland 12, Ohio. **F**

Circle 629 on Page 19

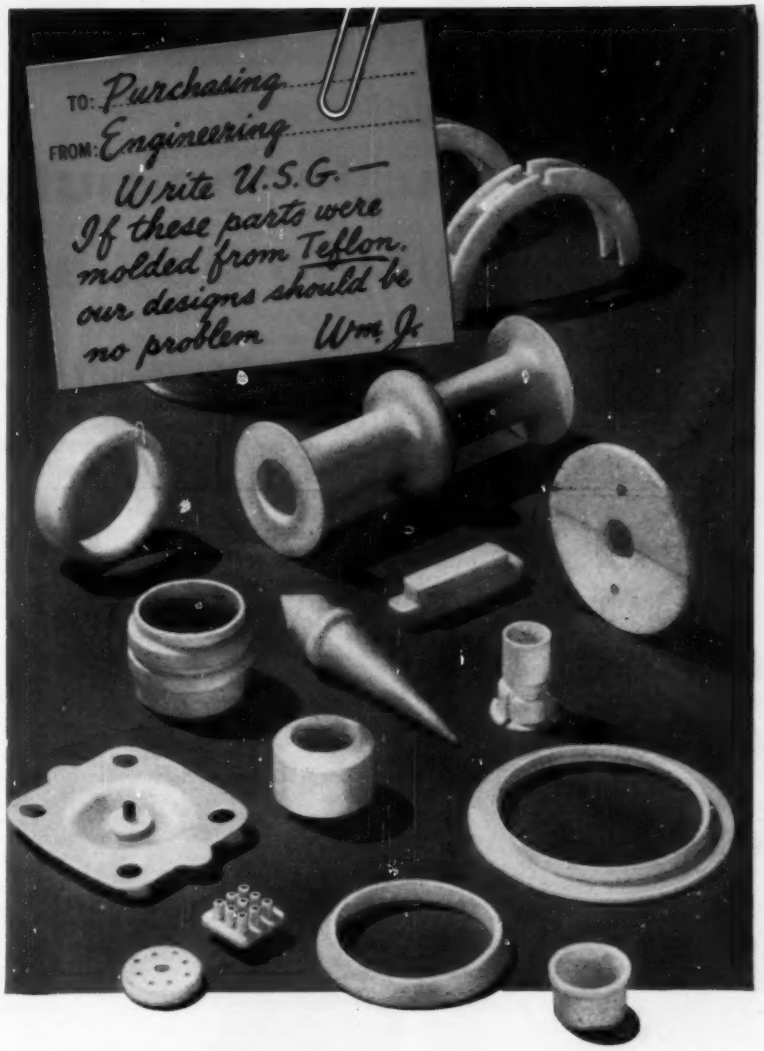
Permanent-Magnet Motors

miniature units have rotatable brush holder

Series A permanent-magnet motors are slightly over 1 in. in diameter. They incorporate a rotatable



brush holder which is adjustable for best commutation and power output. All armatures are wound with heavy wiring utilizing Mylar insulation. Motor shafts are stainless steel and rotate on fully shielded ball bearings. Motors designed



Never underestimate the molding possibilities of TEFLON*, in the hands of United States Gasket.

True, it is probably the most difficult of all plastics to mold. But U.S.G. specializes in difficult moldings, involving precision tolerances, intricate shapes, inserts, molding around metallic structures, etc.

They are equipped with unusual "know-how" gained as pioneers and leaders in fluorocarbon plastics fabrication, and the most modern specialized facilities and techniques for cold molding and sintering of TEFLON T.F.E., as well as the injection molding of KEL-F† and the new thermoplastic TEFLON F.E.P.

Send us your difficult fluorocarbon molding problems for quotations. And call upon us, too, for your requirements of fluorocarbon and nylon sheets, discs, tape, rods, tubing, bars, cylinders, etc., from the world's largest and most complete stocks.

For prompt service, contact one of The Garlock Packing Company's 30 sales offices and warehouses throughout the U.S. and Canada, or write

†*M.M.&M. Trademark*
**du Pont Trademark*

United States Gasket Company
Camden 1, New Jersey

United States Gasket *Plastics Division of* **GARLOCK**

Circle 501 on Page 19

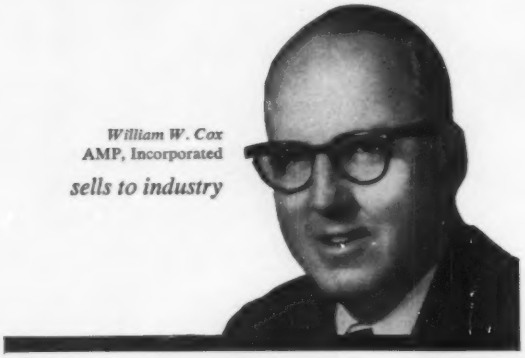
Can specialized business publication advertising actually sell?

By reputation, salesmen are reluctant to credit anything but their own selling efforts for getting names on the dotted line.

Actually, it's quite a different story. The most successful salesmen will tell you two important things about selling. 1. That the selling process is largely a matter of communicating ideas. 2. And that specialized business publication advertising can help importantly to register information with prospects.

Of course each salesman will express this in his own way ... but they all agree that selling would be far more difficult without the advertising that appears in the industrial, trade, and professional publications that serve the specialized markets to which they sell.

Here, for instance, is what a salesman has to say about this kind of advertising:



William W. Cox
AMP, Incorporated
sells to industry

Says Mr. Cox:

"The quickest way we can introduce a product is by introducing it through advertising in business papers. That way we get it around faster than we can by word of mouth alone. On occasion my home office has inquiries out to me before I can get to the customer or prospect to introduce a new product. They've already seen it in a trade magazine.

"It is interesting to note that within the last two weeks I received a survey which shows about 80% of the new customers we get on our books come through our trade publication advertising. Of course, our company is only 15 years old and we have grown from what you might say, *nothing*, to the biggest in our business. Certainly a lot of that has come from our advertising campaigns. Our name is known throughout the world right now, purely because of our advertising program. When I go to a prospect now, they know my company, they know my product... it makes my job easier, and opens doors when I have to make cold calls."

Ask your own salesmen what your company's business publication advertising does for them. If their answers are generally favorable you can be sure that your business publication advertising is really helping them sell. If too many answers are negative it could well pay you to review your advertising objectives—and to make sure the publications that carry your advertising are read by the men who must be sold.

How salesmen use their companies' advertising to get more business

Here's a useful and effective package of ideas for the sales manager, advertising manager or agency man who would like to get more horsepower out of his advertising. Send for a free copy of the pocket size booklet entitled, "How Salesmen Use Advertising in Their Selling," which reports the successful methods employed by eleven salesmen who tell how they get more value out of their companies' advertising.

You'll find represented many interesting variations in how they do this. Some are very ingenious; all are effective. You can be sure that more of your salesmen will use your advertising after they read how others get business through these simple methods.

The coupon is for your convenience in sending for your free copy. Then, if you decide you want to provide your salesmen with additional copies, they are available from NBP Headquarters in Washington, at twenty-five cents each. Or if you choose you can reprint the material yourself and distribute it as widely as you please. But first, send for your free copy.

NATIONAL BUSINESS PUBLICATIONS, INC.
Department 4D
1413 K Street, N. W.
Washington 5, D. C. **STerling 3-7533**

Please send me a free copy of the NBP booklet "How Salesmen Use Advertising in Their Selling."

Name _____

Title _____

Company _____

Street Address _____

City _____ Zone _____ State _____

National Business Publications, Inc.

NBP

... each of which serves a specialized market in a specific industry, trade or profession.

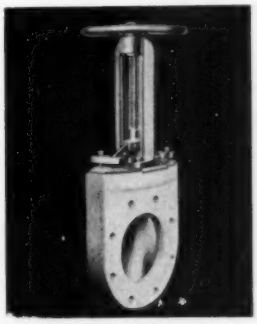
for operation from 6, 12, and 27.5 v are available from stock. Other windings or mechanical modifications are available on special order. **Servo-Tek Products Co.,** 1086 Goffle Rd., Hawthorne, N. J.

Circle 630 on Page 19

Plastic Body Valve

in sizes from 3 to 12 in.

Bonnetless, 150-psi valve has a plastic body, glass-reinforced with high-impact polyester resin to provide corrosion resistance. Four types of gate material are avail-



able with the valve. Body material withstands temperatures to 300 F. Vibrationproof, the valve resists acids and alkalis, and is suitable for use with plastic pipelines. It is available with alloy or PVC plastic blade, and with quick-opening lever, air cylinder, or motor mount for motorized operation. Sizes range from 3 to 12 in. **W. G. Rovang & Associates Inc.,** 1945 N. Columbia Blvd., Portland 7, Oreg.

Circle 631 on Page 19

Magnetic-Amplifier Relay

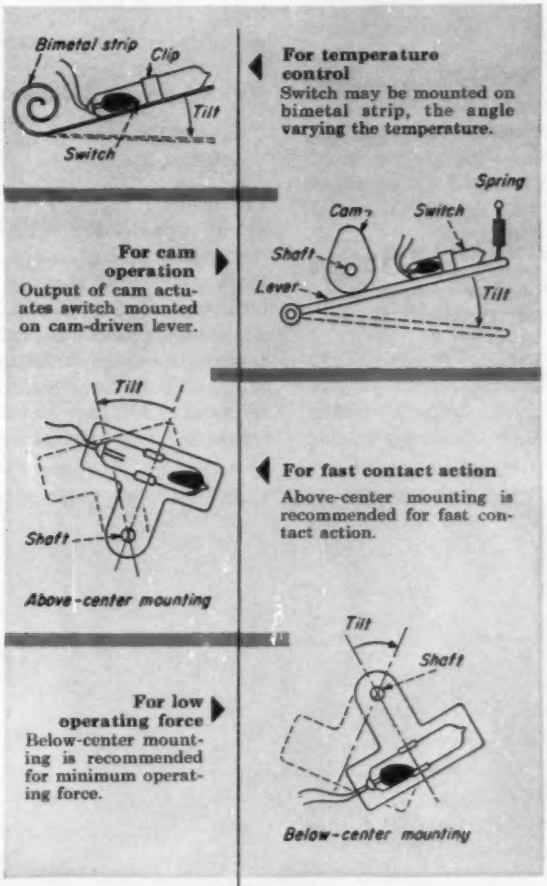
operates over or under a preset critical speed

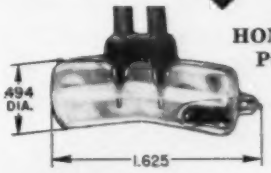
Model 3440 over/under magnetic-amplifier speed-control relay is designed for use with a magnetic pickup which may be mounted near a rotating gear. The tubeless amplifier and relay operate either over or under a preset critical speed. Gear teeth passing the pickup at 0.005-in. spacing, and traveling 40 to 50 ips peripheral speed, provide a signal which is amplified by the device to provide single-pole double-throw switching of electrical loads up to 5 amp

H MICRO SWITCH Precision Switches

4 ways HONEYWELL Mercury Switches are used in modern design applications

HONEYWELL Mercury Switches include over 1000 variations to meet individual needs. MICRO SWITCH field engineers provide special help with mounting methods, actuating linkages and shock-proof enclosures. HONEYWELL Mercury Switches are ideal for locations where dust, fumes, spray or splash are present.





HONEYWELL Mercury Pulse Switch for slow rotating devices

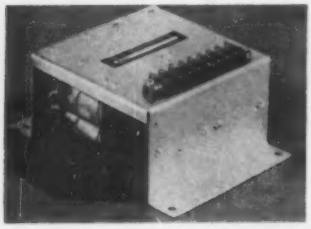
This switch has proved exceedingly useful for direct one-to-one counting on slow rotating devices. Pulse action is accomplished by the curved glass tube. These include business machines, timing devices, vending machines, signaling devices, etc.

For complete information on HONEYWELL *Mercury Switches send for Catalog 90.*

MICRO SWITCH
A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY
FREEPORT, ILLINOIS
First in Precision Switching

Circle 503 on Page 19

New Parts



noninductive. Critical speed for the relay is set by adjusting spacing between magnetic pickup and actuating metal. Unit is suitable as a safety device for machine tools and similar applications. **Electro Products Laboratories Inc.,** 4500 N. Ravenswood Ave., Chicago 40, Ill.

Circle 632 on Page 19

Printed-Circuit Laminates

have improved environmental and electrical characteristics

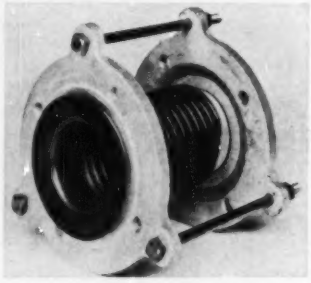
Fluoroply - P and Fluoroply - E printed-circuit laminates possess physical characteristics of their base materials. Fluoroply-P employs a base of punchable grade XXXP phenolic with a film of fluorocarbon between base board and copper surfaces. Fluoroply-E is similar to Fluoroply-P, with epoxy fiber glass as the base material. Upon etching, fluorocarbon surfaces are exposed which provide high surface resistivity and arc resistance. Broad surfaces of the base material are sealed, reducing moisture absorption and improving environmental performance. **International Resistance Co.,** 401 N. Broad St., Philadelphia 8, Pa.

Circle 633 on Page 19

Molded Teflon Bellows

have high burst strength and flex life

Fluoroflex-T bellows are molded of a high-density virgin Teflon compound. They cover low and medium-pressure service. Characteristics include dynamic working pressures up to 120 psi, full vacuum service, bending deflection to 70 deg, and axial movement to 2 in. or more. Molding process maintains the linear orientation through the bellows convolutions, providing high tensile strength and fatigue life. Bellows withstand temperatures to 450 F, and are unaffected by all chemicals except molten alkali metals and fluorine at ele-



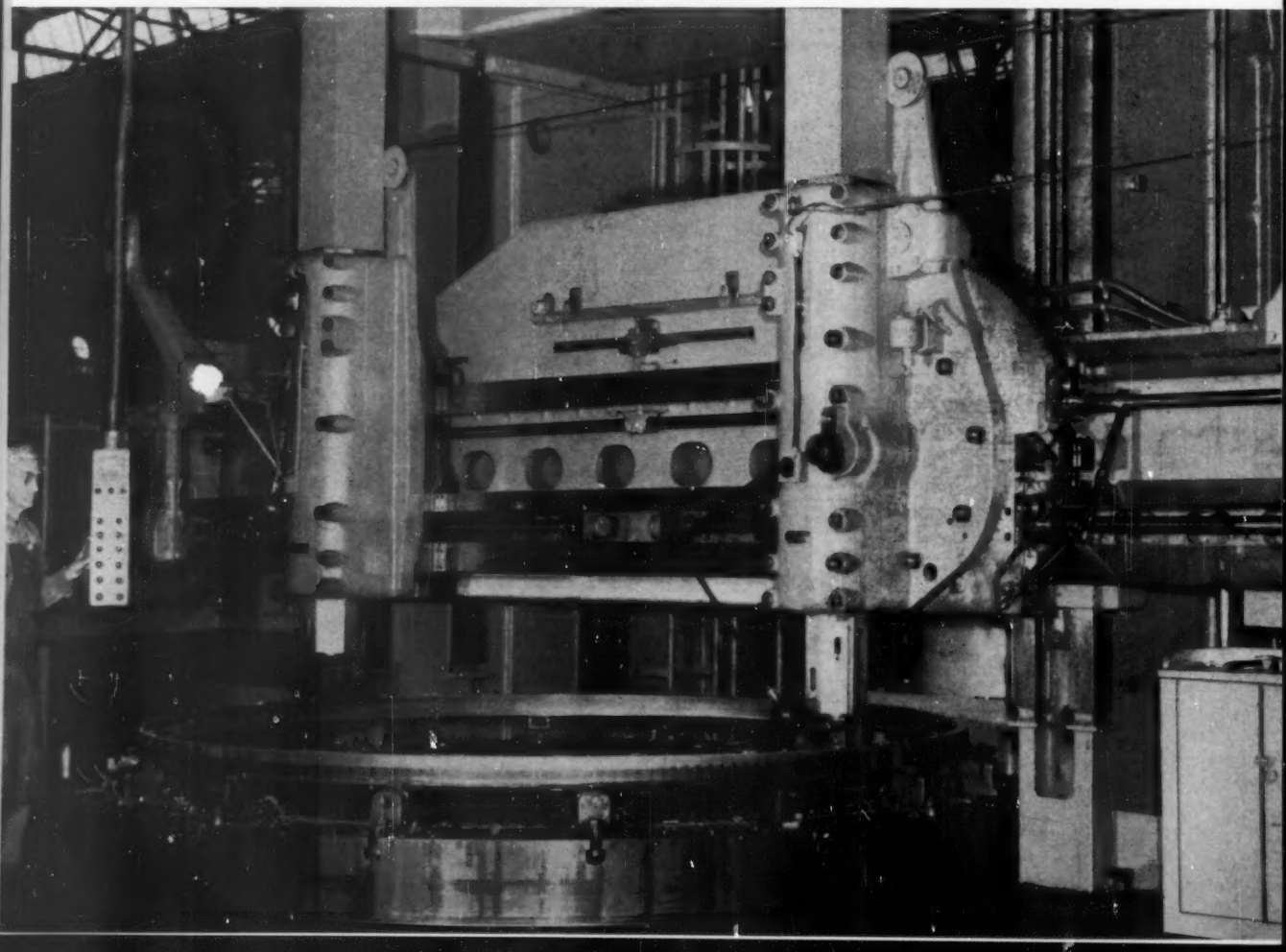
vated temperatures and pressures. **Resistoflex Corp.,** Woodland Rd., Roseland, N. J.

Circle 634 on Page 19

Heavy-Duty Clutch

has detachable drive and driven hubs

Series 4200 electromagnetic disc clutch is for applications such as ball mills, rod mills and kilns. It is a heavy-duty unit with maxi-



mum torque of 120,000 lb-ft and 4878 sq in. lining area. Detachable drive and driven hubs permit removing the entire clutch-operating mechanism without disturbing shafts. **Stearns Electric Corp.,** 120 N. Broadway, Milwaukee 2, Wis.

Circle 635 on Page 19

Adhesives

bond treated Teflon to itself or other materials

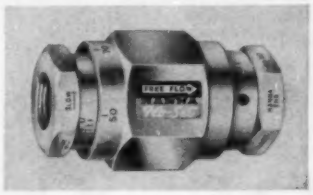
Ray-Bond R-86004, R-86024, and R-81001 permit the effective bonding of treated Teflon to wood, steel, glass, aluminum, copper, ceramics, plastics, or any other material that will bond with an adhesive. They meet the requirements for strength, chemical resistance, flexibility, and temperature resistance for practically all Teflon-bonding applications. Either one or both surfaces of Teflon can be treated for bonding. R-86004 is recommended for use where maximum chemical resistance is required. R-86024 is for the economical bonding of Teflon for dry applications. R-81001 is recommended for bonds that must endure heat or must be flexible. It resists temperatures to the limit for Teflon, and can be used to bond assemblies subject to temperatures to 400 F. Bond resists attack by oil and solvents. Adhesives Dept., **Raybestos-Manhattan Inc.,** Bridgeport 2, Conn.

Circle 636 on Page 19

Speed-Control Valve

controls piston speeds of hydraulic cylinders

Flo-Set 1000 hydraulic speed-control valve is rated for 1000-psi service, and is available in ¼, ⅜, ½, and ¾-in. sizes. Valve controls piston speeds of hydraulic cylinders and speeds of other hydraulically operated devices. When used with cylinders, valve permits in-stroke and outstroke speeds to be regulated separately. Flow can be controlled from zero to desired capacity with one revolution of calibrated adjustment sleeve. Valve



is locked in position with a set-screw and locking collar. **Hanna Engineering Works,** 1765 Elston Ave., Chicago 22, Ill.

Circle 637 on Page 19

Printed-Circuit Connector

has dip-solder terminals

GPCW connector, with terminals for dip-soldering and wire-wrap, permits the economical joining of printed-circuit boards at right an-

Westinghouse AV-DRIVE triples production on 14-inch boring mill

This mill at the Standard Steel Works Division of Baldwin-Lima-Hamilton Corporation, Burnham Plant, is doing the work formerly done by three belt-driven units, since it was equipped with a Westinghouse AV-Drive.

In addition to precision and adjustable speed necessary for turning, facing and boring, Westinghouse AV-Drives give Baldwin-Lima-Hamilton the versatility needed for profitable use of their huge metalworking facilities.

Do you have an adjustable speed drive problem? Ask your nearby Westinghouse representative about the AV-Drive. Or, write Westinghouse Electric Corporation, 3 Gateway Center, P.O. Box 868, Pittsburgh 30, Pennsylvania. J-22096

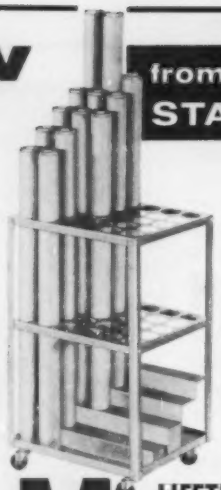
POWER-UP starts with CONTROL

YOU CAN BE SURE... IF IT'S Westinghouse

Circle 504 on Page 19

NEW from STACOR

The Stacor "Lifetime" Quality Line



Blueprint Files

Drafting Tables

Reference Tables

Tracing Tables

Taborets

- Blueprints • Charts
- Drawings • Plans
- Tracings • Maps

where you want them

when you want them

Holds 30-tubes (2¼" ID)

$25. (without tubes)

LIFETIME STEEL

PLAN-MOBILE

LIBERAL DEALER DISCOUNTS

Write, wire, phone RIGHT NOW for descriptive literature.

Attractive, compact mobile unit . . . makes material instantly available for reference, changes or additions. Moves easily and quietly on ball-bearing casters. Stepped bottom makes titles clearly visible . . . rolled plans readily accessible.

Also comes in 60-tube capacity priced at $35.00 (without tubes). 2¼" ID sturdy covered tubes with metal caps and bases are available in both 43" and 55" lengths.

Stacor Since 1932

STACOR EQUIPMENT CO.

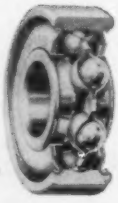
273 Emmet Street Newark 5, N. J. • **Bigelow 2-6600**

Circle 502 on Page 19

Don't Pay for Precision You Don't Need

New RMB Miniature Ball Bearings

Now Available with ABEC-1 Tolerances



There are many applications that just don't require the precision of miniature ball bearings made to ABEC-5 tolerances. Yet, many designers felt they had to sacrifice the advantages of using a miniature ball bearing because of the high cost of these precision products. Often, less than satisfactory substitutes were used.

This is no longer necessary!

RMB now offers, in addition to their high precision series, famous Filmoseal sealed bearings—the only sealed miniature ball bearing—made to ABEC-1 tolerances, to handle those slightly less demanding applications where cost is a primary consideration. Open radial Conrad-type bearings are also available in this new grade. A wide range of sizes is available from 3/16" (0.1875") to ½" (.5000") OD including many metric sizes.

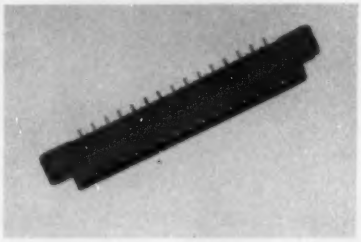
Write for your copy of the new RMB miniature Bearing Catalog which gives full details on these as well as the entire line of quality RMB bearings. Ask for Bulletin 61.

LANDIS & GYR, INC.

45 West 45th Street NewYork 36, N.Y.

Circle 505 on Page 19

New Parts



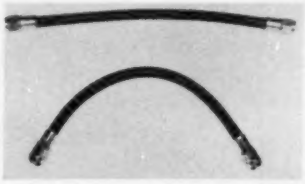
gles. Contacts, of heat-treated beryllium copper, retain contact force after repeated insertions and withdrawals. Connector is available in melamine, plaskon alkyd, or dyall-phalate. At present the connector, with 15 and 22 contacts, spaced 5/32 in. apart for 1/16-in. boards, is available from stock, molded in high-strength, glass-fiber filled plaskon alkyd. Electronics Div., **Gorn Electric Co. Inc.**, 845 Main St., Stamford, Conn.

Circle 638 on Page 19

High-Temperature Hose

contains no metal reinforcement

Fluoroflex-T R536 flexible hose is a corrosionproof, nonswelling, noncontaminating hose for use at elevated temperatures. Containing no metal reinforcement, it combines excellent high-voltage insulation, protection against corona and



moisture absorption, high flex life, and vibration resistance. **Resistoflex Corp.**, Woodland Road, Roseland, N. J.

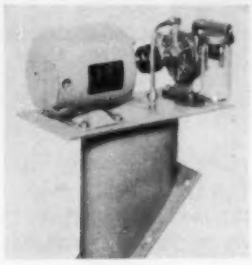
Circle 639 on Page 19

Gear-Case Exhauster

is used with a variety of gear cases

Gear-case exhauster draws a partial vacuum in the gear case, allowing air flow into the case to prevent oil from leaking out. Exhauster can be applied to a variety of gear cases. Vacuum pump is driven through a flexible coupling by a ¼-hp motor. Filter tank,

mounted between gear case and pump intake, removes oil from evacuated air before dried air enters the rotary pump. Oil, under gravity, flows back into gear case



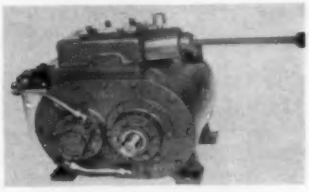
without piping. Pump maintains a vacuum of 3 to 5 in. of mercury. **A & A Mfg. Co. Inc.**, 712 S. 12th St., Milwaukee 4, Wis.

Circle 640 on Page 19

Heavy-Duty Transmission

has capacity to 150 hp

Series 14800-PF transmission has a self-contained pump and filter, along with oil seals to keep out abrasive dust. Four speed changes



are available with a step-up ratio of 1:3 or reduction up to 10:1 overall. Transmission has capacity to 150 hp when directly connected to a motor running at 3470 rpm. Unit is arranged for horizontal or vertical application, and provisions for remote control are available. **Western Mfg. Co.**, 3400 Scotten, Detroit 10, Mich. H

Circle 641 on Page 19

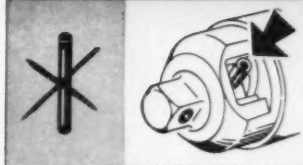
Temperature Control System

provides controlled speed for fans or pumps

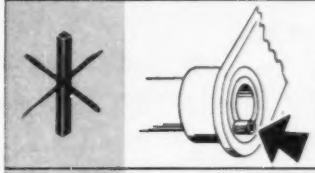
Automatic temperature control system consists of a U. S. Varidrive equipped with Varitrol automatic control, temperature-sensing transmitter, and control panel. The pneumatic system provides controlled variable speed for fans or pumps in heat-exchange processes. It holds the product-output tem-

FASTENER PROBLEM

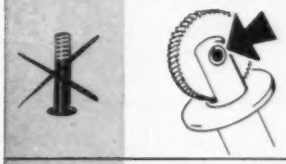
6 ways Rollpin simplifies fastening operations



REPLACING A GROOVED PIN . . . in this application, Rollpin serves as a stop pin in a ratchet wrench adaptor. With its light weight and high shear strength, Rollpin functions perfectly . . . cuts assembly costs.

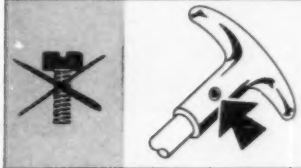


REPLACING A KEY . . . Rollpin demonstrates its ability to do away with precision tolerances, in this heating system damper arm. Faster, cheaper and more satisfactory than previous assemblies.



REPLACING A RIVET SHAFT . . . Rollpin serves as an axle for the sparkwheel of a cigarette lighter. No riveting or threading necessary . . . faster assembly. Note flush, clean fit.

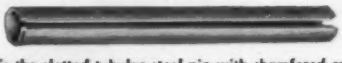
REPLACING A COTTER PIN . . . Rollpin assembly time is shorter, service life ten times longer. Vibration-proof flush fit. Easily removable.



REPLACING A SET SCREW . . . to fasten automobile brake handle a short length Rollpin is self-retained in the hand grip but can easily be driven into over-drilled hole in shaft for simple handle removal.

REPLACING A CLEVIS PIN . . . here Rollpin holds firmly in clevis, permits free action of moving member. Rollpin application shown is the plate of a home workshop tool.

WHERE CAN YOU USE THIS SIMPLE FASTENER?



Rollpin is the slotted tubular steel pin with chamfered ends that is cutting production and maintenance costs in every class of industry.

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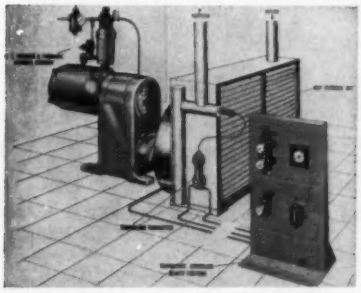


perature within 1 per cent of desired value. System can be used in conjunction with heat-exchange systems operating at pressures to 1000 psi. Gas-filled bulb in the transmitter senses the desired temperature and generates a proportional pneumatic signal to the control on the drive. Drive slows down or speeds up, altering speed of driven fan or pump. **U. S. Electrical Motors Inc.**, Box 2058, Terminal Annex, Los Angeles 54, Calif.

Circle 642 on Page 19

Trigger-Switch

controls electric circuits in mobile equipment

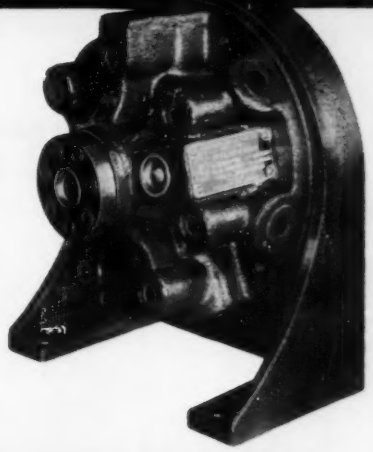
Type R trigger-switch is a momentary-contact switch in a pistol-grip handle, installed at the end of a heavy-duty cable. It facilitates control of electric circuits in mobile equipment, and provides freedom of movement for better visibility or safety. Pistol-grip is molded high-impact phenolic. The

switch is waterproof, and trigger travel is adjustable. Unit meets Navy specifications, and has an electrical rating of 10 amp 125 v ac at 0.80 power factor. Switch is available with a four-conductor cable of any length. **Electro Switch Corp.**, 167 King Ave., Weymouth 88, Mass.

Circle 643 on Page 19

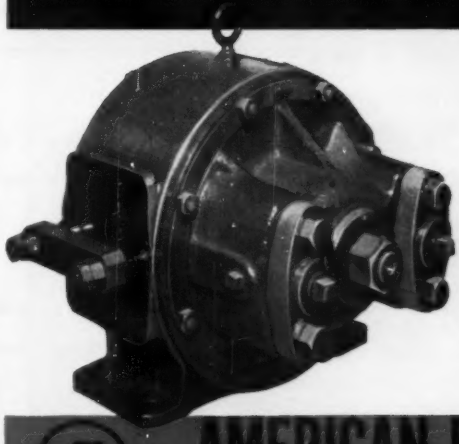
For highest quality
when the pressure's on . . . it's
HELE-SHAW and HYDRAMITE
HYDRAULIC PUMPS

for constant displacement . . .
HYDRAMITE



- Pressures to 5,000 psi
- Capacities of 3, 5, 10 gpm and up
- No supercharging needed
- Efficiencies over 85%
- Either rotation for direct drive

for variable displacement . . .
HELE-SHAW



- Instantly reversible
- From 0 to 3,000 psi
- Capacities from 3 to 110 gpm
- Infinitely variable discharge
- Many types of controls

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Circle 508 on Page 19

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Circle 644 on Page 19

Rosette Strain Gages

have high sensitivity and stability

SR-4 foil-type rosette strain gages of bonded-filament construction have high sensitivity and stability. They need no lateral corrections except in most precise testing problems, and withstand temperatures to 300 F in continuous service. Thin, flexible construction permits easy application to test specimens. Units consists of three single-element foil gages, individually insulated and mounted in

Circle 510 on Page 19→

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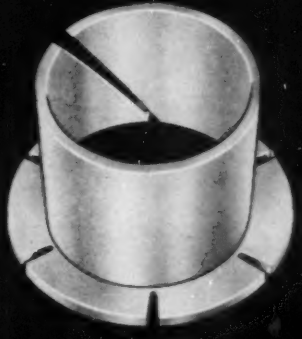

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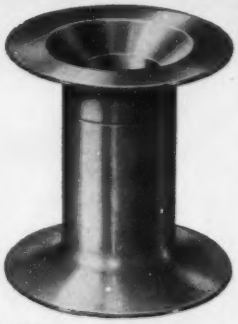
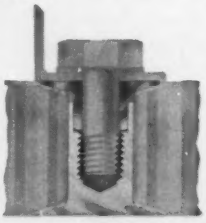


Lightweight, high column strength aluminum or stainless steel FASCO Spacers are available in a variety of designs.



FASCO Threaded Self-Locking Spacer is specified for honeycomb panels of North American's F-100 Super Sabre.

This is another example of how Delron Products solve the critical fastening problems of industry!

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Engineering Equipment

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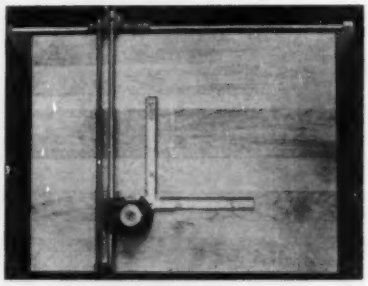
Circle 645 on Page 19

Drafting Machine

permits use of drawing board at any angle

Drafting machine permits work with drawing board at any angle, without changing counterweights or counterbalances. Controls are conveniently located for one-hand operation. Machine can be used



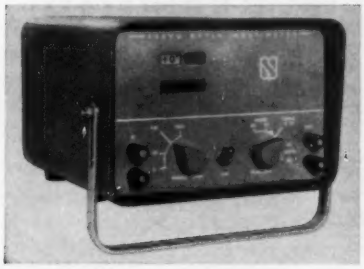
with any standard scale plates. Lightweight indexing head is precision machined for immediate 15-deg angle settings through a full 360 deg. Vernier settings give intermediate angles to 5 min. Finger-pressure controls lock or release machine at any angle setting. Long, continuous parallel, horizontal, or vertical lines can be drawn. Standard models are available for board coverage from 24 x 30 to 48 x 96 in. Vertical wall-board units are also available to 8 x 30 ft. **Glideline Corp.**, 300 S. Potomac St., Waynesboro, Pa.

Circle 646 on Page 19

Computer Test Instrument

measures ac-dc ratios, voltages, and resistance

Servo-Ratio Multimeter is an accurate computer test instrument which combines the functions of an ac-dc ratiometer, an ac-dc voltmeter, and an ohmmeter in one portable unit. It computes voltage ratios by dividing voltage to be measured by the reference volt-



age obtained from the computer. Motor-driven, position-type servo mechanism is utilized. Simplification and reliability are incorporated through the use of printed circuits. Chassis and front panel slide into a compact aluminum case to form a unit which can be operated horizontally or vertically. Front panel provides a four-digit drum counter for readout. **Union Switch & Signal,** Div., Westinghouse Air Brake Co., Swissvale, Pa.

Circle 647 on Page 19

Oscillograph

is 36-channel, direct-reading unit

Model 1012 Visicorder produces records that are immediately visible and usable, recording directly on paper which needs no processing. It is a 36-channel unit which incorporates pushbutton control for changing speeds. Instrument has five speeds in each of three ranges, from 0.1 to 160 ips. Frequency response is 3000 cps, without use of peaked amplifiers. Writing speed is up to 20,000 ips, using 12-in. paper. Instrument accommodates 200 ft of record paper, which can be loaded in daylight. Unit is designed for 115-v, 50, 60, or 400-cycle operation. **Heiland Div.,** Minneapolis-Honeywell Regulator Co., 5200 E. Evans Ave., Denver, Colo.

Circle 648 on Page 19

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Circle 512 on Page 19

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57,000 ft. per min.

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This book provides an integrated survey of latest automation techniques as applied to various manufacturing and metal-working processes. Emphasis is on practice, and material is treated in terms of processes rather than specific industries or products.

Automation is covered in terms of the three basic functions of production: Materials handling, processing, and quality control. Major topics include basic principles relevant to manufacturing processes, implications of automation, and principles of feedback control loop with basic devices for effecting hydraulic, pneumatic, electric, and electronic control functions.

A separate section covers particular manufacturing processes such as metal working, metal cutting, pressworking, joining, heat treating, casting, and production of ferrous and nonferrous metals.

Electronic Designers' Handbook. *By R. W. Landee, D. C. Davis, and A. P. Albrecht;* 1200 *pages,* 6 *by* 9 *in., clothbound; published by McGraw-Hill Book Co. Inc.,* 330 *West* 42*nd St., New York* 36, *N. Y.; available from* MACHINE DESIGN, $16.50 *postpaid.*

This handbook provides fundamentals and data to aid in the design of all types of electronic equipment. Many circuits are covered by theoretical and technical discussions and explanations, design examples to show application of theory, and graphical and tabular data needed in day-to-day design work.

The electronic field is covered in 23 sections ranging from vacuum-

tube fundamentals and voltage and power amplifiers to computer and servomechanism techniques and waveform and network analysis. Detailed design data are presented.

Ideas, Inventions, and Patents. *By Robert A. Buckles; 270 pages, 6 by 9 in., clothbound; published by John Wiley & Sons Inc., 440 Fourth Ave., New York 16, N. Y.; available from* MACHINE DESIGN, *$5.95 postpaid.*

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Mathematics for Science and Engineering. *By Philip L. Alger, Consulting Engineer, General Electric Co.; 360 pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, *$6.95 postpaid.*

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Circle 514 on Page 19

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multiple circuit switch for machine tools

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lation of cost estimates to engineering, and such basic factors as tool life, machinability, and cutting-tool materials.

Specific estimating problems associated with such tools and operations as high-speed drills, radial drilling, milling, turret lathes, broaching, etc., are covered. Developments covered in the machine-tool field include ceramic and tungsten-carbide cutting tools, throwaway cutting tools, and electronic computers and programmers as applied to automatic machining processes.

Process Instrument and Controls Handbook. *Edited by Douglas M. Considine; 1286 pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York 36, N. Y.; available from* MACHINE DESIGN, $19.50 *postpaid.*

This book presents operating and design fundamentals of measurement and automatic control systems used in process fields. It serves as a review of principles of many different types of measurement and control processes, a guide to selection of instruments and automatic controls for specific jobs, and as a compilation of formulas, constants, and other engineering data for aid in solving instrumentation problems.

Among subjects covered are measurement standards, primary elements, measurement systems, indicators and recorders, automatic controllers, timers and program controllers, electric and pneumatic telemetering, final control elements, fundamental principles of process control, and mathematical techniques for solving automatic control problems.

Association Publications

Directory of Steel Foundries in the United States, Canada, and Mexico. *280 pages, 6 by 9 in., paperbound; published by and available from Steel Founders' Society of America, 606 Terminal Tower, Cleveland 13, Ohio; $15.00 per copy.*

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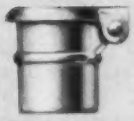
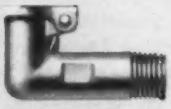


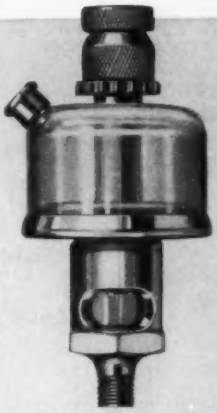
Style G — No. 505
Beaded Drive

Style GB — No. 527
Ball Valve



Style L — No. 1204
Brass Elbow (Threaded)

SIGHT GRAVITY FEED OILERS



Rate of oil flow regulated by needle valve, directly observed through sight glass in stem. Shut-off knob does not affect needle valve adjustment. Visible oil supply. Non-breakable. Tops in convenience and dependability, at low cost. Style NFU—No. 3602-A.

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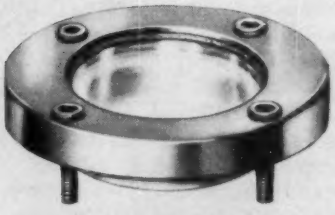
This oil gauge plug permits instant checking of oil level within a transmission or gear case. For use where construction permits insertion in tapped hole. A valuable addition to any such equipment — at very low cost. Style BW—No. 4042.

GEAR CASE GAUGES



Screw mounted, to set flush. Glass port is backed with white enameled reflector, to make oil level (in gear case or transmission) readily visible, even in dim light. Style CW — No. 4032.

SIGHT GAUGES

For use where rate of oil flow must be regulated to suit changing operating conditions. Needle valve permits extremely accurate adjustment of oil feed. Sight glass provides direct observation of rate of oil flow. Accuracy and convenience at a moderate price. Style PF—No. 4290.

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Management Bookshelf. *54 pages, 5½ by 8½ in., paperbound; available on letterhead request from the American Management Association, 1515 Broadway, Times Square, New York 36, N. Y.*

This latest edition of the 1957-58 catalog contains a listing of all current AMA publications, periodicals, and films. Major publications include AMA research and special reports. Contents of series publications include AMA research and special reports. Contents of series publications appearing since 1955 are described, and titles are listed for those which appeared before 1955.

Film listings include a four-part series in full color and sound on data processing and computer systems and their significance to management.

Welding Handbook. *Edited by Arthur L. Phillips; 560 pages, 6 by 9 in., clothbound; published by and available from the American Welding Society, 33 West 39th St., New York 18, N. Y.; $9.00 per copy.*

This first section of the new five-volume *Welding Handbook* deals with fundamentals of welding and contains over 500 illustrations and tables.

Material covered includes standard welding terms, engineering tables of temperature data, conversion factors, and alloys; fundamentals of metallurgy, joint properties, thermal and mechanical treatment of weldments, cost factors, and test methods.

Subsequent sections of the handbook will cover welding processes and practices, metals, and welding applications.

Career Satisfactions of Professional Engineers in Industry. *84 pages, 6 by 9 in., paperbound; available from the*

Professional Engineers Conference Board For Industry, 2029 K St. N. W., Washington 6, D. C.; $1.50 per copy to NSPE members, $3.00 per copy to nonmembers.

This report presents findings based on interviews with professional engineers in industry. The purpose of the study was to examine the thinking of engineers at three different stages in their careers: Early, at 3 to 6 years' experience, midpoint, at 10 to 15 years' experience, and late, at 20 to 25 years' experience. Eleven companies in eight industries were included in the survey. Each company is among the top 200 largest corporations in the U. S., and each is a major employer of engineering talent.

Included in the report are experiences and backgrounds of engineers surveyed, their career outlooks, satisfactions and frustrations on the job, and values of the successful engineer.

References on Fatigue, 1956. *64 pages, 8½ by 11 in., paperbound; available from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.; $3.00 per copy.*

This is a list of references to articles published in 1956 dealing with fatigue of structures and materials. References are so arranged that sheets can be cut apart for filing according to any desired plan. Abstracts have been included where possible.

Copper and Copper-Alloy Welding Rods. *13 pages, 6 by 9 in., paperbound; published by and available from American Welding Society, 33 West 39th St., New York 18, N. Y.; or from American Society of Testing Materials, 1916 Race St., Philadelphia 3, Pa.; 40 cents per copy.*

Eleven classifications in this new second edition include copper, copper-silicon, copper-tin, copper-nickel, copper-zinc, and copper-aluminum welding rods. Chemical composition, mechanical properties, and usability characteristics of each classification are included together with tests for verifying these properties.

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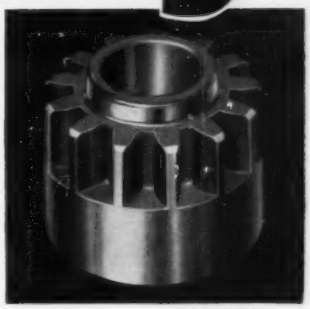

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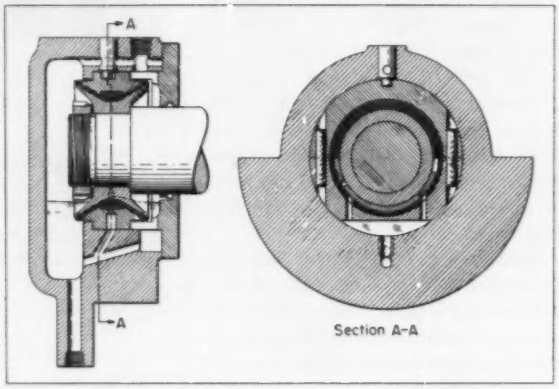
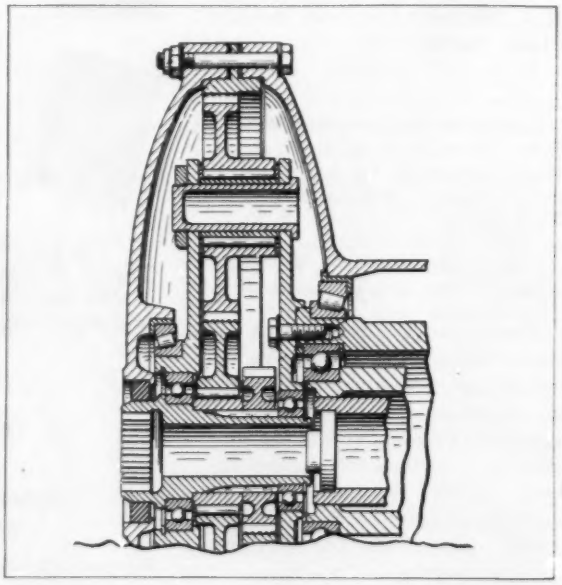
Axial thrust is carried by a wedge-shaped oil film in an angular-contact thrust bearing. Sliding valve plate, located between the lower bearing half and the

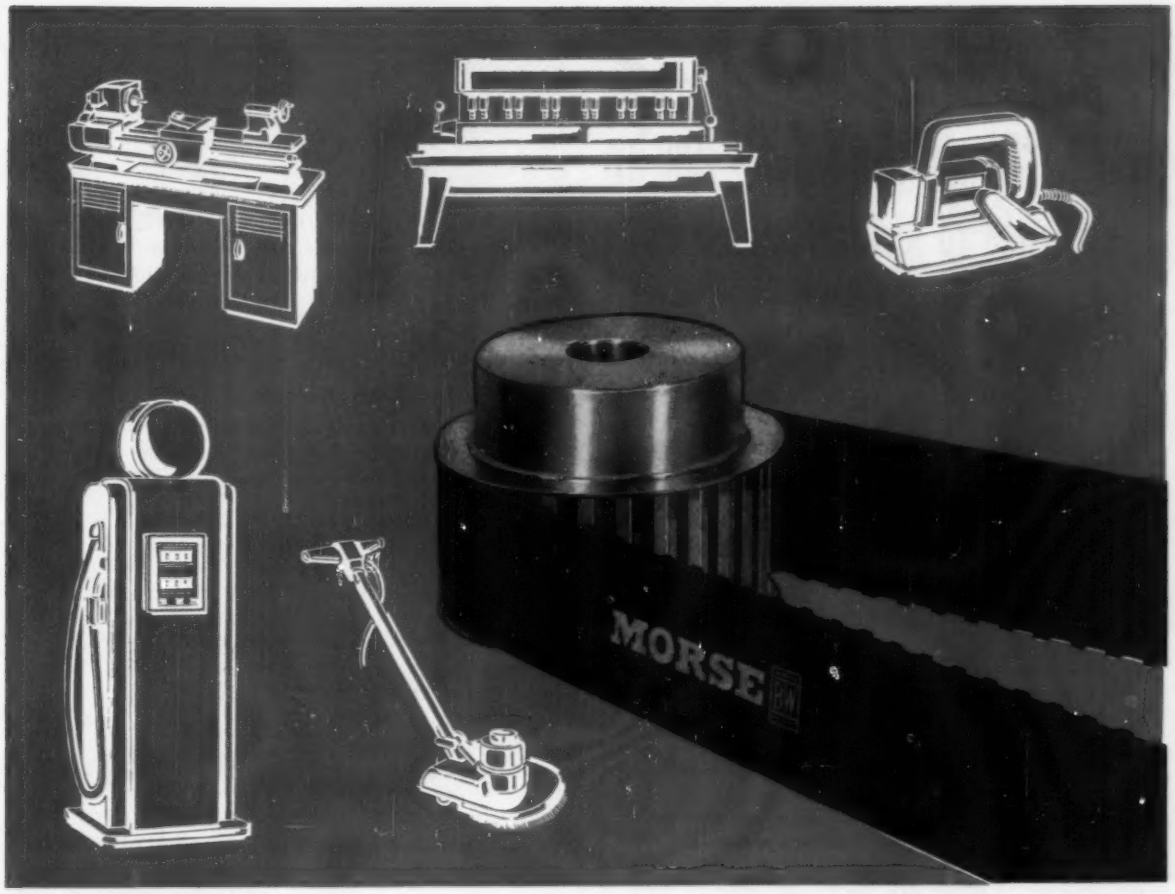


shaft, directs lubricating oil to the bearing face that supports the load regardless of direction of shaft rotation. Wearing faces of the flanged, sleeve-type thrust bearing are babbitted. *Patent* 2,804,357 *assigned to Worthington Corp. by William C. Krutzsch.*

Planetary Reduction Gearing

Maximum tooth-tip compressive stress is substantially lower than in conventional gearing in a planetary-gear reducer employing an idler sun gear and auxiliary idler pinions. Idler sun gear, which revolves freely on the input shaft, meshes with primary planet





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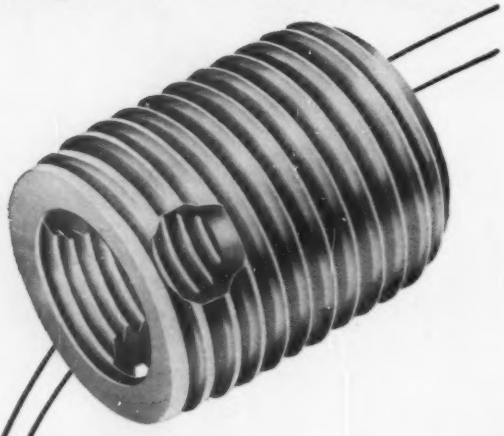

Acting on the request of many industrial design engineers for a TAP-LOK INSERT that meets aircraft standards, we now offer the H-Series INSERT. Design features are:

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The new insert works on the same principle as the regular slotted TAP-LOK INSERT. It is driven into the hole with the standard TAP-LOK INSERT DRIVER. Adequate chip flow is provided while the insert cuts its thread into the base material.

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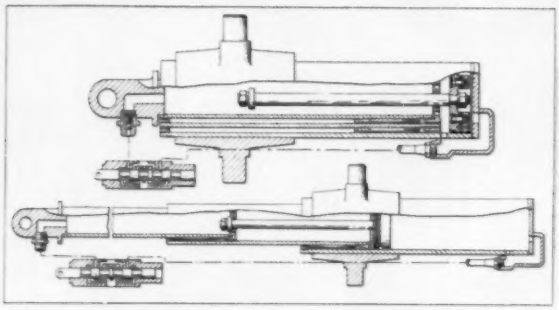
Also manufacturers of Groov-Pins for positive locking press fit.

Noteworthy Patents

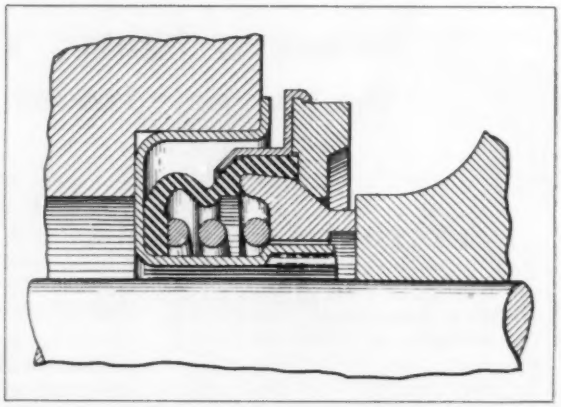
pinions and provides a driving connection between them and the auxiliary idler pinions. Idler pinions mesh with a stationary ring gear fixed in the unit housing. Speed ratio of the unit depends on the relative diameters of the driving sun gear, the primary planet pinions, and the ring gear. In a typical design with 9:1 ratio, maximum tooth-tip compressive stress is about 40 per cent of that of a conventional arrangement. *Patent* 2,804,785 *assigned to Indiana Gear Works Inc. by Alfred Mendez.*

Telescoping Linear Actuator

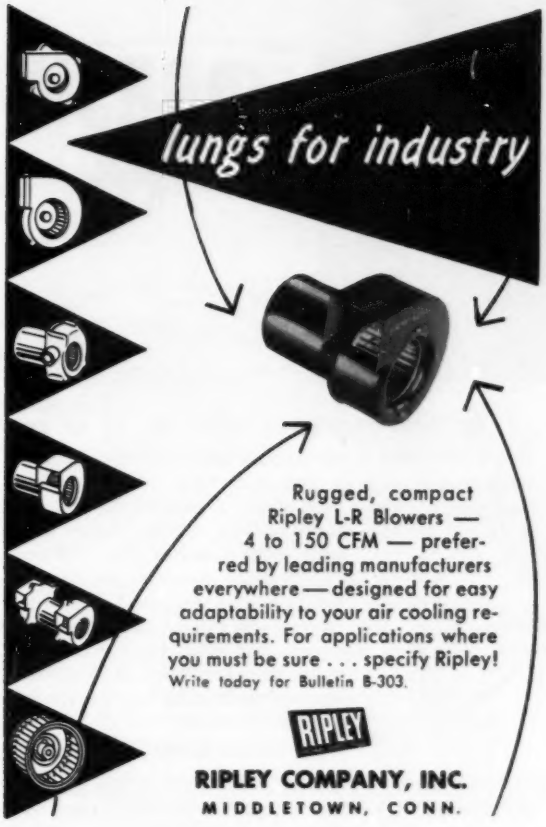
System of check and control valves gives a telescoping linear actuator full-power extension through a complete stroke and full-power retraction to an intermediate collapsed position. In service, return stroke is completed by an external force. In a typical application, actuator is used to tilt a load-carrying body so that its center of gravity moves past the pivot point, with hydraulic power initiating the return stroke. *Patent* 2,746,428 *assigned to Gar Wood Industries by Norbert T. Starr.*



Vibration-Damped Seal



Torsional oscillations giving rise to objectionable squeals in operation are damped out by an inertia ring in a mechanical seal assembly. Shown here in a typical water-pump installation (impeller right), the unit employs an annular stabilizing-weight in frictional contact with a conical surface on the seal washer to absorb torsional energy. *Patent* 2,798,750 *assigned to Crane Packing Co. by Harry Tankus.*



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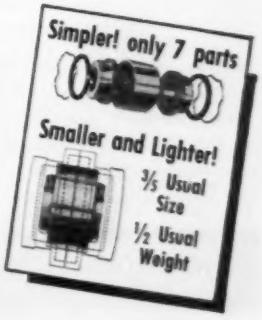

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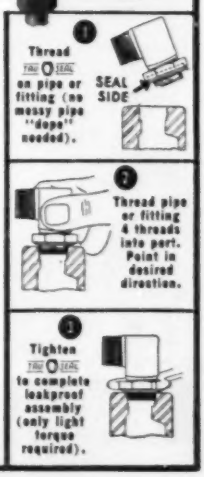
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SEAL SIDE
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Thread pipe or fitting 4 threads into port. Point in desired direction.
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Tighten TRU-O-SEAL to complete leakproof assembly (only light torque required).

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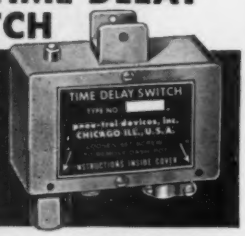
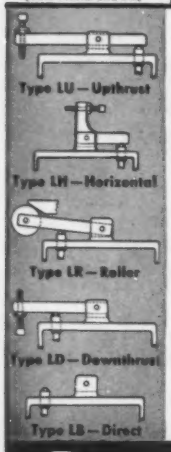


For any type actuation Left or Right Hand. (Left Hand shown)



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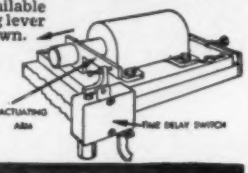

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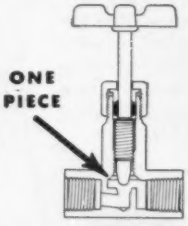

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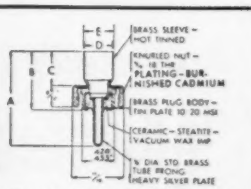
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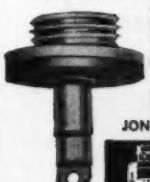

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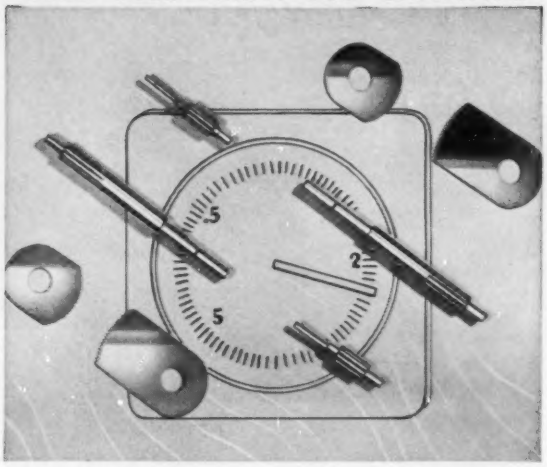

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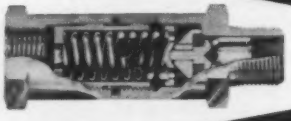

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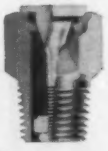

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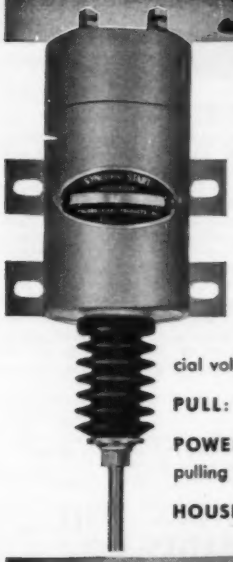

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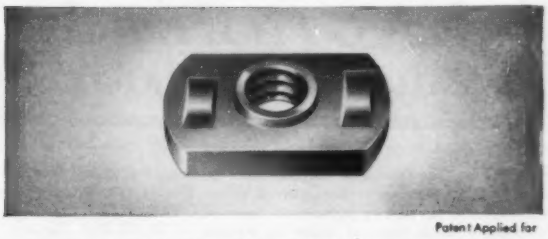

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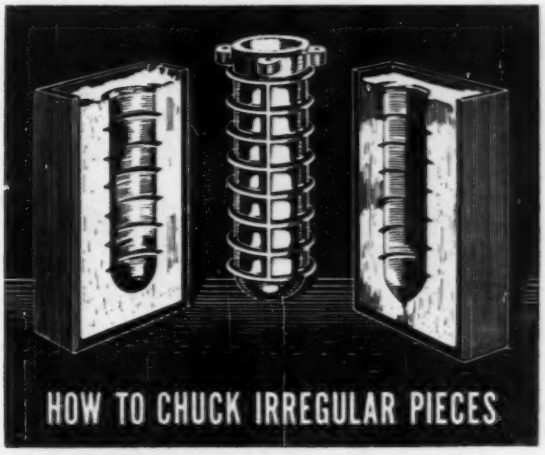

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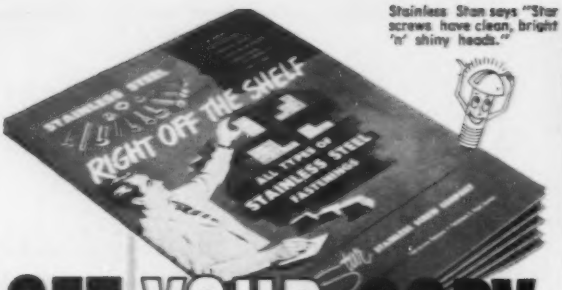

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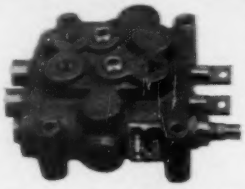

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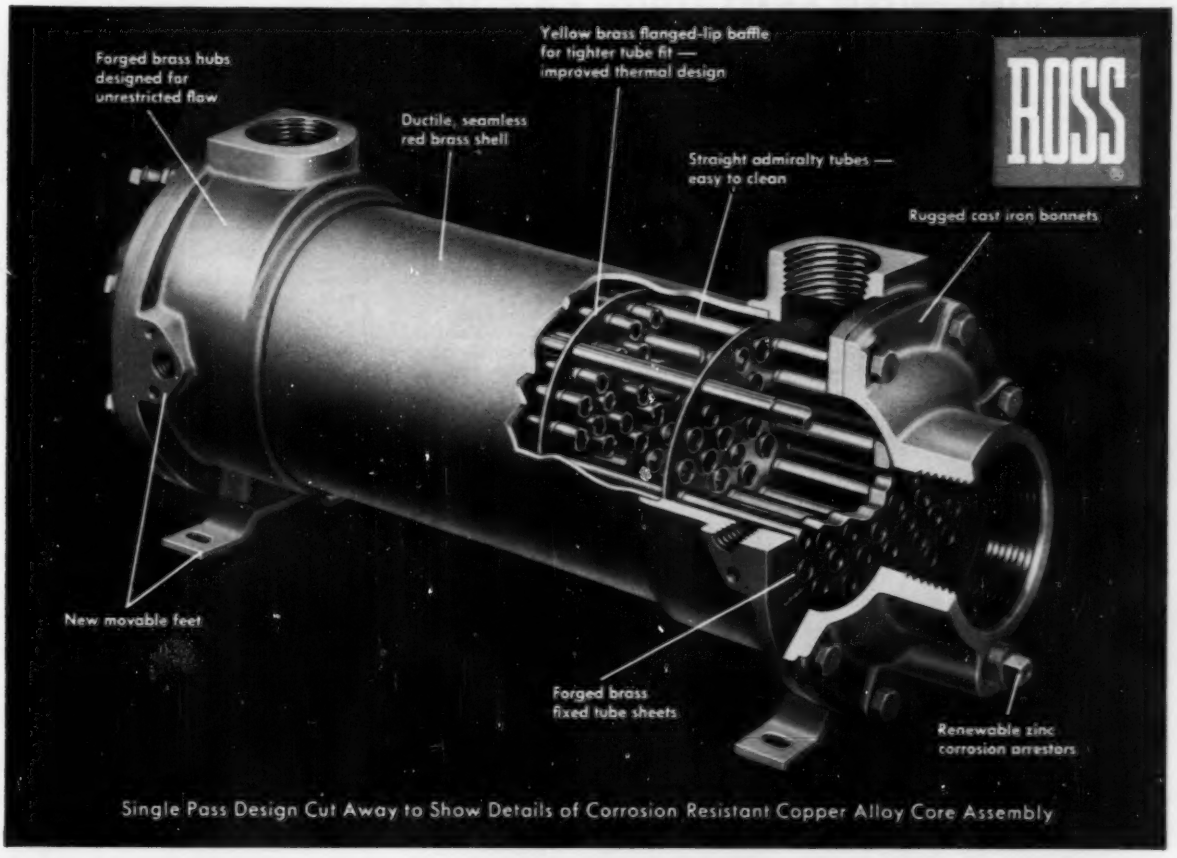
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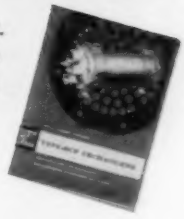

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Fastener Facts

by Henry Peterson, Chief Engineer — Judson L. Thomson Mfg. Co.

DESIGN PRODUCTION & PURCHASING DATA

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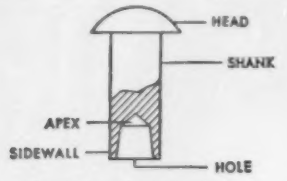

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You specify semi-tubular rivets when you want to combine the high shear and compression strength of solid rivets with low-cost, high-speed fastening. The required strength is inherent in the design of Thomson Semi-Tubular Rivets.

Shallow holes in solid shanks distinguish semi-tubular rivets from other types. The hole is seldom deeper than shank diameter. Its depth is determined by clinch requirements of specific applications. A general rule is to select a rivet with length equal to the thickness of the materials *plus* 55% of the diameter of the shank. A Thomson engineer can quickly specify the correct rivet length and hole depth for any particular semi-tubular riveting application.

Semi-tubular rivet applications call for pre-drilled or punched holes in the materials to be fastened: metals, plastics, wood, ceramics and other hard materials. The size of the prepared holes is an important design consideration. When holes are too small, rivets choke. When too large, rivets buckle. To avoid either error, make sure that each hole is about 7% larger than the maximum shank diameter of the rivet. In most cases, the setting process causes shank expansion sufficient to fill the hole. Again, Thomson engineering is at your service to help you match rivet and hole sizes.

High shear strength of semi-tubular rivets is further assured by Thomson production methods. All Thomson Semi-Tubular Rivets are made from specially prepared wire by the cold heading or upsetting process. This results in fasteners with the uniform structure and *inherent strength of forgings* . . . properties not achieved by screw-machine rivet production.

Standard materials used to produce Thomson Semi-Tubular Rivets include aluminum, brass, copper, nickel-silver, low-carbon steel and stainless steel. For special electrical and electronic contacts, coin silver, fine silver, palladium and other precious metals may be specified.

Finishing to specifications is another service of interest to design engineers. Rivets can be plated with brass, cadmium, copper, nickel, tin, zinc, etc. Morever, they can be oxidized or finished in japanned colors to match the original equipment or product.

Low fastening costs result from the application of Thomson Semi-Tubular Rivets with automatic rivet-setting machines. The low cost of rivets, as compared with most other fasteners, combined with high machine speeds invariably leads to production line economies. Machines are low in initial cost and require little maintenance. Furthermore, they can be operated by unskilled labor.

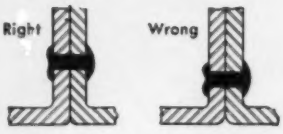
FLOOR-TYPE FOOT-OPERATED — FLOOR-TYPE MOTOR-OPERATED

HIGH PRODUCTION RIVET-SETTING MACHINES

Thomson has developed more than 200 styles of modern, high speed machines which can be adapted to innumerable fastening jobs. These machines are divided into three basic models: floor type with foot-pedal operation, floor type with motor operation, and bench type with motor operation. All permit automatic hopper feed for maximum speed, and some motor driven floor models are equipped for multiple rivet-setting.

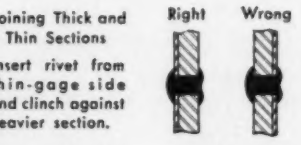
Special work-handling devices accelerate riveting operations. Radial or turret feeds are common accessories for machines geared to high-production fastening of parts, as are all types of special loading fixtures. Thomson selects the proper machine to do your job most efficiently and custom-tools it to fit your fastening requirements.

DESIGN PRACTICES



Clearing Corners

Allow plenty of room between hole and flange for anvil clearance.

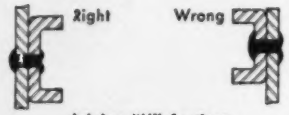


Joining Thick and Thin Sections

Insert rivet from thin-gage side and clinch against heavier section.

Avoid Over-Sized Holes

When holes are too large, rivet may buckle during clinching operation.



Joining "U" Sections

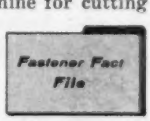
The wider the channel, the easier the riveting operation. Clinching inside "U" leaves driving and feeding mechanisms out in the open.

DESIGN & ENGINEERING SERVICE

We will gladly evaluate your fastening problems at little or no cost. Contact us while designs can still be modified for lowest cost fastening method. Simply send sketches, prints, or preferably samples of actual work.

FREE "FASTENER FACT FILE"

Be one of the first to profit from our new manual on all phases of riveting. It covers rivet types, applications, materials, finishes, and other factors that determine selection of the right design, rivet and machine for cutting fastening costs. Request your copy today. Write Judson L. Thomson Mfg. Co., Dept. B, Waltham 54, Massachusetts.



JUDSON L. THOMSON MFG. CO., WALTHAM 54, MASS.

Farval lubrication helps side milling machine work at faster speeds

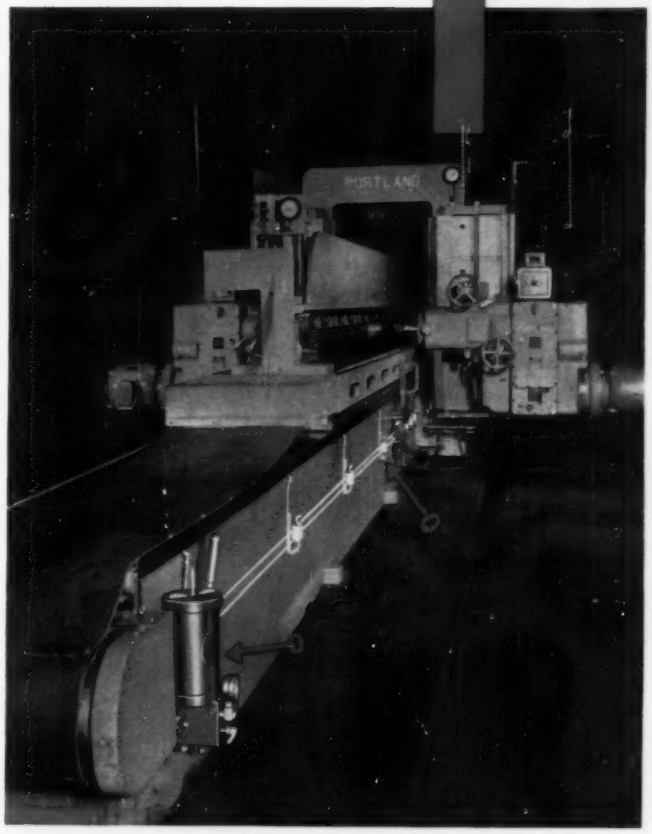
FARVAL—
Studies in Centralized Lubrication
No. 213

● Designed and built by Portland Machine Tool Works, this machine is used for side milling laminated steel plates in a western Pennsylvania steel plant. Employing a climb cut, both milling heads generate extreme downward pressures on the table ways. To protect against these extreme pressures on the ways, a Farval lubrication system was installed.

Result—unusually high speeds in milling are possible and usual, and not an hour of production time has been lost due to faulty lubrication. Periodic operation of the Farval hand pump keeps the ways working perfectly.

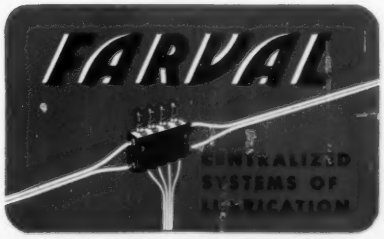
Free Lubrication Survey—Why not find out where Farval can save you time and money? One of our lubrication engineers will be glad to inspect your plant equipment. He will present a written analysis, without obligation, of what Farval can do for you. And for the complete Farval story, write for Bulletin 26-S, The Farval Corporation, 3287 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing.
In Canada: Peacock Brothers Limited.



KEYS TO ADEQUATE LUBRICATION—The familiar Dualine Valve manifolds, dual lubricant lines and central pumping station are the sign of Farval—the sign that a machine is being properly lubricated. Farval manually operated and automatic systems protect millions of industrial bearings.

Above is the Portland conversion side milling machine on which ways are now protected by a Farval system.



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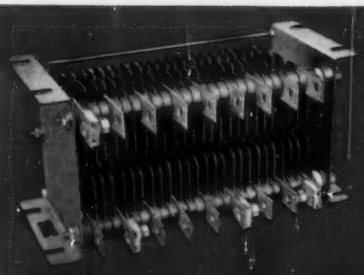
When you need HEAVY DUTY RESISTORS

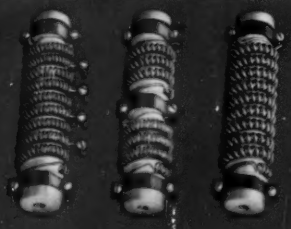
insist on the finest...

insist on Cutler-Hammer



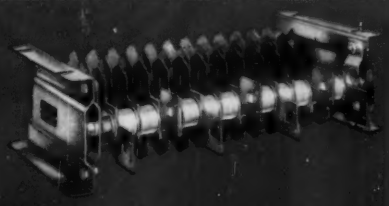
CAST GRID RESISTORS

Cutler-Hammer Bulletin 11010 Cast Grid Resistors are built to take it. Their extra rugged construction makes them ideal for those tough applications where severe overloads are to be expected. The individual cast grids are supported at three points within the sturdy steel frame and thoroughly insulated with mica tubes and washers. All grid terminals are easily accessible.



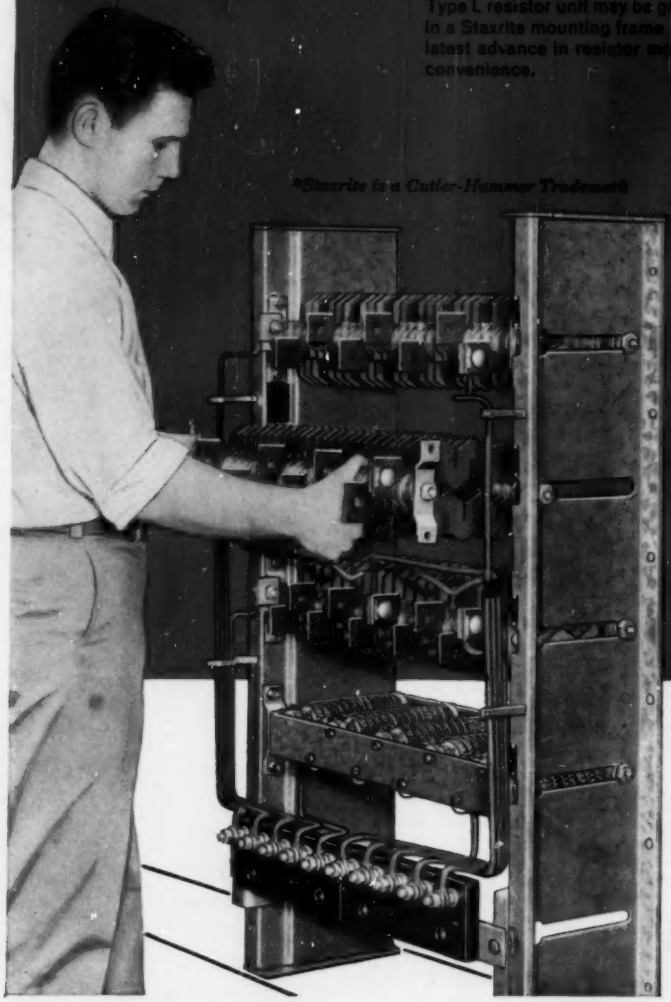
UNIT TYPE RESISTORS

These Bulletin 11003 Type L Resistors are available in a wide range of resistance values and capacities for either A-c or D-c service . . . perfect for scores of applications requiring a light weight, compact resistor element. Cutler-Hammer Type L resistors may be mounted separately or grouped in any of four standard size resistor frames. Note, multiple Type L resistor unit may be grouped in a Staxrite mounting frame . . . the latest advance in resistor mounting convenience.



NON-BREAKABLE RESISTORS

Cutler-Hammer's Bulletin 11011 Non-breakable Resistor with exclusive "draw-out" design is the choice among experienced engineers everywhere. Grids are stamped from a chromium steel alloy and then welded together forming a continuous current path with a stabilized resistance value. These resistors are shock-proof, vibration-proof, and corrosion-resistant. Their high thermal capacity makes them ideal for heavy duty applications. And the "draw-out" design is extra value at no extra cost. All units slide in and out easily and quickly without disturbing the end frames, adjacent resistor units, or mounting members. "Draw-out" design will save you time and expense during installation, maintenance, and alterations.



*Staxrite is a Cutler-Hammer Trademark

Staxrite*—Here is the most modern and efficient means of mounting multiple resistor units . . . a Cutler-Hammer "first", a Cutler-Hammer exclusive. These units are free-standing and only require the floor area of a single resistor box, but they can accommodate up to nine resistor frames in a single unit. The Staxrite mounting frame packs more resistor material in a given space than ever before, and yet every resistor unit is easily reached and serviced because of the "draw-out" design. Complete terminal board wired assemblies practically eliminate costly on-the-job wiring. Unwired assemblies also available. The Staxrite mounting frame will handle the Type L resistor frame, the non-breakable resistor frame or a combination of both. Save time, save space, save money with Staxrite.

CUTLER-HAMMER
MOTOR CONTROL
C-H

Write today for further data on heavy duty resistors and the Staxrite mounting frame. CUTLER-HAMMER Inc., 1310 St. Paul Avenue, Milwaukee 1, Wis. *Associate:* Canadian Cutler-Hammer Ltd., Toronto.

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